



TECHNICAL NOTE 364

1980-82
SALINITY
STATUS
REPORT:

Results of Bureau of Land Management
Studies on Public Lands in the
Upper Colorado River Basin



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1980-82 SALINITY STATUS REPORT:

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on Public Lands in the Upper Colorado River Basin

June, 1984

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I. INTRODUCTION

In 1975, the Bureau of Land Management established a team to study salt runoff from public lands in the Colorado River Basin. The emphasis of the program shifted in 1983 from studies to the identification of opportunities to reduce salinity through watershed treatments and other land management activities.

The BLM has issued two Salinity Status Reports (USDI, 1978; USDI, 1980). The first (1977 Status Report) described the salinity problem and provided a thorough review of salinity literature, including quantitative and qualitative descriptions of salt pickup and transport mechanisms occurring on public lands. The second (1978-79 Status Report) reviewed alternatives for managing salinity on public lands, and proposed three specific point-source salinity control projects.

The purpose of this report is to summarize the most important results and conclusions from BLM studies completed during the 1980-82 period. In addition, we review specific techniques and alternatives for managing salinity from diffuse overland sources. Studies to be reviewed are:

1. Monitoring study of ephemeral washes in the Price River Basin, Utah, for storm runoff and water quality.
2. Monitoring study of three basins at Badger Wash, Colorado, for runoff and water quality.
3. Studies of soil geomorphology, soil salinity, and vegetation in the Woodside, Utah, area.
4. Rainfall simulation study of surface runoff and water quality on three soil-landform units on Mancos shale.
5. Rainfall simulation study of the effects of trampling and vegetative cover on runoff and water quality on Mancos shale rangelands.
6. Survey study of sediment accumulations in retention basins in Mancos shale badlands.
7. Monitoring study of summer baseflow salt yields at eighteen locations on streams in the Price River Basin, Utah.
8. Study of salt yields associated with the construction and operation of a wildlife management area at Pariette Draw, Utah.

Management techniques considered as alternatives for controlling salinity from diffuse overland sources are reviewed. They include land treatments such as contour furrows and trenches, and structural techniques such as retention basins, gully plugs and gully headcut controls.

In general, the most saline rangelands have very poor vegetation cover and offer only limited opportunities to manage salinity through grazing management or vegetation management. Those opportunities are discussed.

II. SUMMARY OF IMPORTANT RESULTS AND CONCLUSIONS

1. Annual salt yields were measured at three locations underlain by Mancos shale. Surface runoff produced an average of 0.07 metric tons (t) of salt per hectare (0.03 English tons/acre, hereafter referred to as tons/acre) during 1981 summer and fall convectional storms on three small moderately sloped watersheds on Mancos shale in the Price River Basin. Approximately 0.11 t/ha/yr (0.05 tons/acre/yr) of salt are estimated to have been discharged from three small moderately sloped watersheds on Mancos shale at Badger Wash in western Colorado. Roughly 0.23 t/ha/yr (0.10 tons/acre/yr) of salt and 7.75 t/ha/yr (3.4 tons/acre/yr) of sediment accumulated in a series of small catch basins over a seven-year period on steep Mancos shale badlands near Huntington, Utah.
2. Storm-period salt concentrations are closely related to suspended sediment concentrations except at the onset of runoff. We hypothesize that flushing of concentrated in-channel salts causes a comparatively high ratio of total dissolved solids (TDS) concentration to total solids (TS) concentrations at the onset of runoff.
3. Highest salt and sediment concentrations in three small washes in the Price River Basin, Utah, occurred in the first streamflow event following a long period where no discharge occurred, suggesting sediments and salts became available for transport during that period.
4. Three broad geomorphic units and 11 different soil series in 22 mapping units were recognized and described at the Woodside, Utah salinity study site. Eleven plant communities were recognized and described within the study area. Soil moisture and soil soluble salts appear to be primary factors affecting vegetation distribution and community differences.
5. Salt and sediment yields from steep Mancos shale badland formations are much higher on a per unit area basis than from gently sloped Mancos shale lowlands. Rilling accounts for approximately 80% of the erosion on steep Mancos shale badlands. Interrill erosion accounts for almost all upland erosion on gently sloped Mancos shale lowlands.
6. Livestock trampling on dry, fine, gray, crusted soils on Mancos shale lowlands causes surface crusts to be broken and a temporary increase in soil erodibility. These effects are offset by increased depression storage and higher total infiltration. Higher concentrations of salt and sediment occurred from trampled study plots. However, reduced runoff creates the potential for livestock trampling to reduce total sediment and salt yields from this soil-landform type. We do not expect this conclusion to apply to compactable soils where trampling, especially under moist soil conditions, may decrease infiltration and increase runoff and surface erosion.
7. Baseflows from ground water sources and irrigation return flows in the Price River Basin, Utah, contribute over three times the annual salt load in the Price River at Woodside, Utah, than surface runoff from short-duration summer convectional storms.

8. Irrigation or innundation of saline streamside soils as part of wildlife management or riparian rehabilitation programs may reduce salinity due to channel erosion, but may increase salt leaching from those soils.
9. There is little opportunity to affect salt runoff on highly saline soils on Mancos shale lowlands through either grazing management or vegetation manipulation. This is because good (or even fair) hydrologic condition cannot be achieved even at maximum potential cover. On less saline sites with higher cover potentials, grazing management may result in improved cover and reduced runoff and erosion. However, the lower soil salt content of these sites limits the potential for large reductions in salt yield on a unit area basis.
10. Watershed treatments and structural controls can result in multiple benefits for salinity control, sediment control, forage production, wildlife, water supply and downstream flood control. Salinity benefits will generally be greatest using water retention techniques on highly saline soils. Benefits to forage production (range) will generally be greatest using land treatments e.g. contour furrows on non- to slightly-saline soils. Most retention structures have limited lives and require periodic maintenance to maintain their effectiveness. Land treatments are most effective when they result in improvements in vegetation cover which persist after the effective life of the treatment.
11. Because of the close association between erosion and salinity, good management for forage production, range, and watershed condition (including management for soil loss) will generally provide salinity benefits.

III. SALINITY STUDIES

SALT AND SEDIMENT YIELDS ON EPHEMERAL WASHES: PRICE RIVER BASIN, UTAH¹

Background

Rainfall, stream discharge and water quality data were collected from 1979 to 1981 on three small ephemeral washes--Wattis Branch, Soldier Creek and Coal Creek--in saline geologic settings in the Price River Basin, Utah (Fig. 1). The purpose of the study was to quantify salt and sediment yields, as well as water quality, during transient runoff events. In addition, through an analysis of salt-sediment ratios in the discharge, the importance of erosion and sediment transport as salinity yield mechanisms was further described. Very few data existed previously which depicted total dissolved solids (TDS) and total solids (TS) concentrations in relation to complete storm hydrographs in small ephemeral channels.

Wattis Branch originates in steeply dissected Mancos shale uplands and traverses exposed bottomland shale and alluvium. The basin area is 1,270 ha (3,060 acres). Elevations range from 1,851 m (6,073 ft) to 2,675 m (8,777 ft) and the average slope is 14.7 percent. Fifty percent of the watershed is classified as either a badland soil complex or exposed shale badland.

Soldier Creek and Coal Creek originate in sandstone formations in the lower Book Cliffs, then traverse exposed bottomland shale and alluvium. Basin areas are 324 ha (801 acres) and 106 ha (262 acres), respectively. Elevations range from 1,140 m (3,740 ft) to 1,890 m (6,201 ft) and the average slope is 10.9% in Soldier Creek basin and 9.9% in Coal Creek basin. Soils are primarily gravelly and shaly loams on upland ridges and silt and shaley loams on the bottomlands.

Vegetation in all three sub-basins is sparse and ranges from pinon pine (*Pinus edulis*) and juniper (*Juniperus osteosperma*) on gravelly upland sites to low sagebrush (*Artemisia arbuscula*), rabbitbrush (*Chrysothamnus nauseosus*), shadscale (*Atriplex confertifolia*), Nuttall saltbush (*Atriplex nuttallii*), mat saltbush (*Atriplex corrugata*), and various grasses on bottomlands. Badlands are sparsely vegetated. Precipitation averages less than 250 mm (10 in.) annually. Most runoff-producing precipitation occurs as high intensity, short-duration summer convectional storms. There is little land use, except for some winter and spring grazing by livestock.

Only a few runoff events were successfully monitored during the 1979-80 period because of difficulties encountered with the automatic sampling equipment. In 1981 eighteen runoff events were monitored successfully during late summer and early fall.

¹Detailed study results provided in USDI (1982a), Lin, et al. (1983) and Riley, et al. (1982).

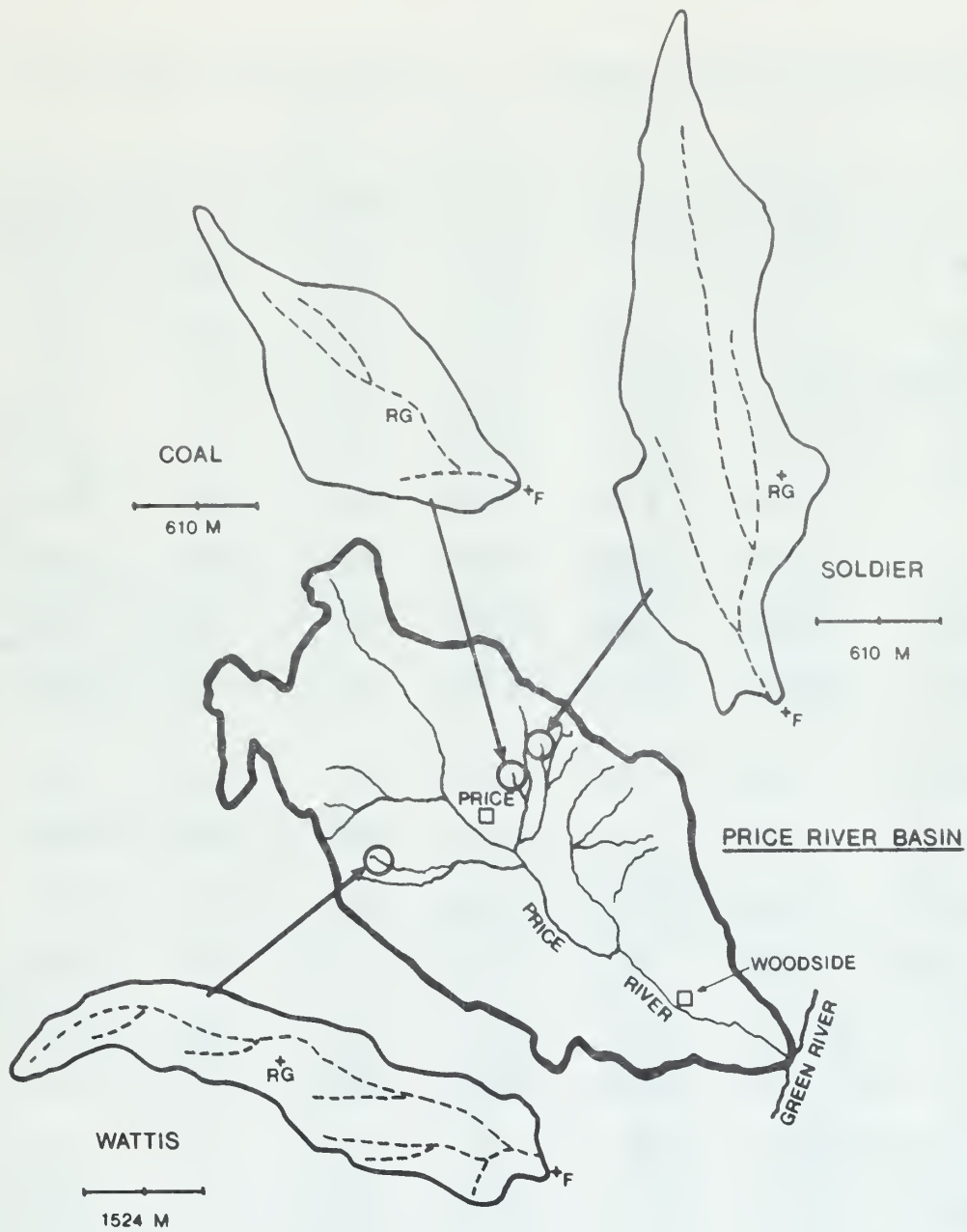


Figure 1. Location of Wattis Branch, Coal Creek and Soldier Creek, Utah.

Results

Precipitation, runoff and water quality data are summarized for the 1981 events in Tables 1 through 3. Average single-storm TS concentrations ranged from 2,783 mg/l on Coal Creek to 267,680 (mg/l) on Wattis Branch. The largest single discharge of TDS was 43 t (47 English tons) and occurred on Wattis Branch.

Table 1. Wattis Drainage Storm Summary

	Date						
	8/23/81	9/5/81	10/3/81	10/11/81	10/11/81	10/16/81	10/17/81
Runoff Volume (RO), m ³	6,868	3,138	3,239	10,256	3,052	14,192	8,439
Time to Peak, hrs	0.7	3.3	0.25	1.3	0.25	2.2	1.3
Duration of Runoff, hrs	1.5	10.0	1.7	6.0	3.0	7.0	7.0
Peak Discharge, m ³ /s	3.7	0.34	2.2	1.6	1.2	2.4	0.7
TDS Load, t	42.9	6.84	17.84	NA	4.94	19.57	11.74
TS Load, t	1,495	185	430	NA	206	547	1,675
Peak TDS, mg/l	60,000	7,000	25,000	NA	1,800	1,500	2,200
Peak TS, mg/l	680,000	100,000	310,000	NA	90,000	54,000	62,000
Average Salt: Solid Ratio, %	2.87	3.67	4.15	NA	2.41	3.58	7.05
Average TDS, mg/l	7,682	2,177	5,495	NA	1,616	1,365	1,391
Average TS, mg/l	267,684	59,292	132,108	NA	67,158	38,414	19,699
Soil Loss, (USLE) t	NA	NA	NA	1,067	309	482	551
Precipitation (P), cm	NA	0.43	0.51	1.27	0.25	1.52	0.43
Runoff/Precip. Ratio	NA	0.0560	0.0476	0.0601	0.0896	0.0698	0.146
Completeness of Samples	C	MF	C	PT	C	C	C
Sampling Method	M	M	M	ISCO	M	ISCO	ISCO

Notes: C = Completely sampled
 PT = Partially sampled
 MF = Initial part of storm event sampled
 NA = Not available
 M = Manual

1 m = 3.281 ft
 1 t = 1.1 tons
 1 mg = 3.53 x 10⁻⁵ oz
 1 liter = 61.02 in³

Table 2. Soldier Creek Storm Summary.

	Date					
	10/3/81	10/4/81	10/11/81	10/13/81	10/15/81	10/16/81
Runoff Volume, m ³	5,883	101	10,949	4,826	12,478	19,765
Time to Peak, hrs	2.3	0.6	1.0	1.0	1.0	3.5
Duration of Runoff, hrs	4.6	2.0	4.5	3.5	4.7	10.0
Peak Discharge, m ³ /s	1.7	.045	3.1	10.5	2.6	2.1
TDS Load, t	9.10	.18	8.77	6.02	14.47	NA
TS Load, t	384.90	.87	174.72	63.61	452.27	NA
Peak TDS, mg/l	9,000	3,000	1,200	2,000	1,900	NA
Peak TS, mg/l	85,000	16,000	17,500	14,000	61,000	NA
Average TDS, mg/l	1,564	1,776	808	1,244	1,154	NA
Average TS, mg/l	65,531	8,621	15,853	13,142	38,414	NA
Average Salt:						
Solid Ratio, %	2.36	20.83	5.02	9.47	3.20	NA
Soil Loss, (USLE) t	NA	NA	24.8	16.5	74.6	32.8
Precipitation (P), cm	1.00	0.51	0.66	0.38	1.02	1.65
Runoff/Precip. Ratio	0.182	0.006	0.512	0.392	0.378	0.370
Comments:	C	C	C	C	C	MF
Method of Sampling	M	M	ISCO	ISCO	ISCO	ISCO

Table 3. Coal Creek Storm Summary.

	Date				
	10/3/81	10/4/81	10/12/81	10/13/81	10/16/81
Runoff Volume, m ³	113	20	1,062	1,039	2,020
Time to Peak, hrs	0.5	0.4	0.3	2.3	1.3
Duration of Runoff, hrs	1.5	1.3	1.6	6.0	7.0
Peak Discharge, m ³ /s	0.055	0.012	03.10	0.240	0.290
TDS Load, t	0.39	.004	.223	.273	.419
TS Load, t	26.21	.06	6.09	9.65	15.20
Peak TDS, mg/l	410	210	250	410	260
Peak TS, mg/l	19,800	3,400	19,000	16,000	12,200
Average TDS, mg/l	380	181	218	262	207
Average TS, mg/l	3,000	2,783	5,715	9,218	5,709
Average Salt:					
Solid Ratio, %	13.0	7.0	3.80	2.83	2.75
Soil Loss, (USLE) Mg	NA	NA	10.5	2.2	12.7
Precipitation (P), cm	0.510	1.02	1.65	.76	1.91
Runoff/Precip. Ratio	0.021	0.0018	0.061	0.129	0.0998
Comments:	C	C	C	C	C
Method of Sampling	M	M	ISCO	ISCO	ISCO

Notes: C = Complete hydrograph sampled
 MF = Initial storm event record are not available
 NA = Not available
 M = Manual
 ISCO = Automatic pumping sampler

1 m = 3.281 ft
 1 t = 1.1 tons
 1 mg = 2.2 x 10⁻⁶ lb
 1 liter = 0.2642 gal

Average single-storm TDS concentrations ranged from 181 mg/l in Coal Creek to 7,680 mg/l in Wattis Branch. Surface runoff during summer convectional storms produced an average of .07 t/ha (.031 tons/acre) of salt during the summer and fall of 1981. Particularly high concentrations of TS and TDS occurred in runoff on all three watersheds during the first monitored storm following a long, dry period, suggesting a flushing of accumulated sediments and salts. TDS/TS ratios in the discharge were generally representative of those found in watershed soils (2-3%). The exception was early on the rising limb of the hydrograph, where a distinct peak in the ratio of TDS to TS occurred. This suggests an initial flushing of concentrated sources of in-channel salts, followed by a predominantly sediment controlled salinity transport mechanism. The average discharge of salts on an annual per hectare basis was .07 t (.031 tons/acre).

Conclusions

The results suggest that salts (possibly occurring as efflorescence) accumulate and concentrate over time on the channel surface. This resulted in high salt to sediment ratios early on the rising limb of the hydrograph. Subsequent salt to sediment ratios were similar to those found in watershed soils, implying that erosion and sediment transport are important salinity transport mechanisms.

SALT YIELDS AT THREE SMALL BASINS; BADGER WASH, COLORADO

Background

Gaging stations were maintained by the U.S. Geological Survey on the Badger Wash Experimental Area in western Colorado at Prairie Dog Reservoir, Middle Basin, and West Twin Basin from 1977 to 1982. Continuous discharge and electrical conductivity (EC) measurements were made and automatic samplers were programmed to collect water quality samples periodically over the duration of ephemeral discharge events. Water samples were analyzed for EC, suspended sediments and TDS. Beginning in 1982, samples were analyzed for suspended sediment concentration. Historic runoff from the 1966 to 1973 period (Lusby, 1979) was then used to extend the average TDS data to estimate a longer-term average annual salt yield from each basin (Table 4). Because of the infrequency of runoff-producing events and the short period of gaging record, only rough estimates of TDS yield and TDS to TS ratios were developed. To further complicate the record, several events early in the gaging period were only partly sampled due to plugging of the sampler intakes.

The Badger Wash experimental area is located approximately 25 km (15 mi) west of Grand Junction, Colorado. The area was set aside for scientific research in rangeland erosion in 1952. The results of the erosion research are reported by Lusby (1979). The climate at Badger Wash is primarily arid to semiarid. Badger Wash Basin is underlain by the Mancos shale formation with thin layers of sandstone outcropping at the higher elevations on the west and north boundaries of the basin. Soils are poorly developed silty clay loams and loams. They are shallow to moderately deep over Mancos shale bedrock. Topography varies from steep slopes at the headwaters to moderate and gentle slopes at lower elevations. Channels are moderately incised on the steep terrain and wider with rounded banks on moderate and gentle terrain. Little evidence of recent accelerated channel erosions exists. Vegetation is a sparse to moderate cover of salt desert shrubs with perennial grasses intermixed. In spring, annual grasses and forbs occupy normally vacant openings between perennial plants.

Badger Wash basin was heavily grazed by cattle beginning in the 1880's. Beginning about 1915, many herds of sheep crossed the basin while trailing from Utah winter ranges back and forth to Colorado mountain summer ranges. The stock driveway was closed in 1957, but the basin continued to be grazed during the winter and spring by resident herds of cattle and sheep until 1966. The basin has been grazed by sheep during the winter only since 1966. A number of fenced watersheds have been ungrazed since 1953.

Results

The overall average discharge of salts from the three basins for the 1966 to 1973 period was 0.11 t/ha/yr (0.05 tons/acre/yr). This figure is roughly comparable to the estimated annual discharge of salts on Wattis Branch (.08 t/ha/yr) and Soldier Creek (.12 t/ha/yr)--two small drainages on Mancos shale in the Price River Basin, Utah (USDI-BLM, 1982a). It is lower than the

estimated average annual discharges of salts from a series of small, steep, badland drainages in Mancos shale near Huntington, Utah (0.23 t/ha/yr)-- assuming 3% salt content in sediment (Jackson and Julander, 1982). The mean salt to sediment ratio in runoff at Badger Wash was 3.8%. This compares to the 3-4% TDS to TS ratios measured at Wattis Branch and Soldier Creek.

Table 4. Summary of TDS discharge from three watersheds at Badger Wash.

Variable	Watershed		
	Prairie Dog	Middle	West Twin
Area (acres)	14		107
(ha)	5.7		43
Mean Slope (percent)	25.8		15.6
Measured Runoff (ac-ft/yr)	0.05	1.6	1.7
(m ³ /yr)	62	1973	2,096
Measured Average TDS (mg/l)	1,380	807	547
Measured Salt Yield			
(tons/mi ² /yr)	3.8	19	8.8
(tons/acre/yr)	0.006	0.030	0.014
(t/ha/yr)	0.014	0.068	0.032
1966-1973 Runoff (ac-ft/yr)	.47	3.1	2.9
(m ³ /yr)	579	3,822	3,576
Estimated Salt Yield, 1966-1973			
(tons/mi ² /yr)	40	37	15
(tons/acre/yr)	0.063	0.058	0.023
(t/ha/yr)	0.144	0.132	0.052
Total average annual salt yield:	31 tons/mi ² /yr		
	0.05 tons/acre/yr		
	0.1 t/ha/yr	0.11	
Mean salt/sediment ratio, TDS/TS (4 samples):	3.8%		

Conclusions

Data from Badger Wash, while inconclusive due to the small number of samples, helps substantiate the rough estimates of salt yield and salt to sediment ratios developed in the Price River Basin for small, moderately steep, ephemeral washes on Mancos shale. Roughly 0.11 t/ha/yr (0.05 tons/acre/yr) of salt were measured in the discharge of three small basins at Badger Wash. This was based on extrapolating runoff and water quality data collected during 1977-82 to runoff and sediment yield collected from 1966-73 during the Badger Wash Erosion Study. The mean salt to sediment ratio (4 samples) was 3.8 percent.

We made no attempt to extrapolate conclusions of the original Badger Wash Erosion and Grazing Study with regard to sediment yield to quantify the effects of livestock grazing on salinity yields. Neither the research design nor the quantity and precision of data collected warranted such an extrapolation. However, surface runoff data from the Price River Basin, Badger Wash and other studies (e.g., Hawkins, et al., 1977; Jackson and Julander, 1982;

USDI-BLM, 1982b) suggest that there is an important, though not inclusive, relationship between salt and suspended sediment yields. The original Badger Wash Erosion and Grazing Study (Lusby, 1979) provided data which supported the hypothesis that grazing intensity and season of use influence annual sediment yields. However, soils in Badger Wash are classified as slightly to moderately saline (USDI, 1978), and support more vegetation than the highly saline soils common to Mancos shale regions. Where soils are more saline and less vegetated, there may be less opportunity to influence sediment and (possible) salt yields through livestock management.

SOIL GEOMORPHOLOGY, SOIL SALINITY AND VEGETATION: WOODSIDE, UTAH

The Woodside salinity research site consists of approximately 2245 ha (5550 acres) located 19 km (12 miles) south of Woodside and 21km (13 miles) northwest of Green River in Emery County, Utah (Figs. 1, 2). The geology of the area consists of eroded pediments of the Bookcliffs (Tertiary) overlying the upper Cretaceous Mancos shale. The Mancos shale dominates the soil survey area although older pediment surfaces are veneered by colluvium from the overlying Mesa Verde group. These colluvial sediments are dominantly sandstone. The pediment deposits overlying the residual Mancos shale vary in thickness but become shallower with increasing distance from the Bookcliffs. Little structural deformation of the bedrock is evident in the area except for a 9 degree dip to the east or into the Bookcliffs. The Mancos shale is a dark carbonaceous, saline, clay deposit of shallow marine origin. Inter-bedded in the formation are siltstone and sandstone layers that are of either shallow marine or terrestrial origin which interfinger in the much more dominant shale units. The overlying Mesa Verde sandstone is a ridge forming, thick, massive, jointed deposit laid down in a subaerial environment.

The desert landscape has a sparse vegetative cover, broad pediment surfaces, and dissected shale badlands. The climate of the Woodside site is extreme with intense hot summers and cold winters. Annual precipitation is generally less than 20 mm (8 inches) most of which falls during the winter in the form of snow. Redistribution of this snow, due to high winds, is frequent and an important factor in distribution of plant communities. Summer thunderstorms periodically cross the area. Frequently, these storms are of very local or isolated nature and do not cover the entire site. Flash floods often fill dry stream beds after these thunderstorms because of the low permeability/high runoff characteristics of the watersheds. Further hydrologic characterization of this site, based upon rainfall simulation studies, is reported elsewhere in this report.

The history of the area's land use has been dominated by livestock grazing. West and Ibrahim, (1968) suggest that most of southeastern Utah has been heavily grazed by sheep. Billings (1949) speculated that paucity of herbaceous vegetation may be due to the affects of past heavy sheep grazing. Stewart, et al (1940) reported that unrestricted grazing of the salt desert shrub vegetation in western Utah has almost eliminated the grass component from the respective plant community types.

Results and Conclusions

Soil Resource Investigations: An Order 3 soil survey has been prepared for the survey area by the Soil Conservation Service. A more detailed survey was prepared as part of this study to better characterize soil depths, texture, chemistry, geomorphic position, vegetation, degree of dissection, slope and rock fragment content. (Schafer, 1981).

Three broad geomorphic units were recognized in the area: 1) a low relief shale pediment and recent alluvial surface in the western third of the study area; 2) a remnant old pediment surface developed from Mesa Verde sandstone

colluvium; and, 3) dissected Mancos shale uplands. Some of the geologic or soil forming materials were identified in several geomorphic units - cutting across geomorphic boundaries. A vertic-like swelling soil was mapped both on the low pediment and on dissected shale surfaces. The data suggest that the parent material for these soils is probably aeolian or windblown in origin, as it occurred on both the low flat areas and along the southern and eastern sides of the outcrops; it also lacks rock fragments and was noticeably silty or very fine sandy loam in texture.

Eleven different soil series in 22 mapping units were recognized in the Woodsite site (Schafer, 1981). Few of these series were established during the Soil Conservation Service inventory of the area. The series identified during the detailed survey were named for the purposes of the survey (Table 1).

Torriorthents varying in depths and texture were the most common soils encountered. The soil series were delineated partially on the basis of the depth to bedrock or paralithic horizon. The paralithic contacts, described as CR horizon herein, and shale were defined as that point where more than 50% of the shale was retained on a 2 mm sieve after one minute of shaking. Slightly weathered shale (R horizon) was defined as a depth where 5% or less of the material passed a 2 mm sieve and shale fragments averaged over 1 cm in thickness. In many instances, a prominent accumulation of salts and gypsum occurred just above the R horizon or the CR horizon, forming a C_{cs} or C_{ca} layer.

Vegetation Resource Inventory: A literature review was included in the vegetation inventory study. The more significant papers reviewed include that of Ibrahim (1963) and West and Ibrahim (1960) which discuss the soil and vegetative relationships of plant communities developing on the Mancos shale of southeastern Utah. In those studies, they identified and described four edaphically controlled climax plant communities on the Mancos shale. The communities identified included: Atriplex confertifolia/Hilaria jamseii, Atriplex nuttallii/nuttalli/Hilaria jamesei, Atriplex nuttallii gardnerii/astor zyloriza and Atriplex corrugata. Lusby, et al. (1963) in a hydrologic study identified Sarcobatus vermiculatus as a dominant on the lower part of the main drainages, Atriplex corrugata as occurring on alkaline flats in the upper reaches of the drainage basins, Artemisia tridentata and Crysothamnus nauseosus on alluvial soils along the drainages, and Atriplex confertifolia and Hilaria jamseii on upland sandy soils. Branson et al (1976) studied several soil factors affecting the geographic distribution of salt desert shrubs. He concluded that the soil moisture relationship was the primary factor affecting distribution of salt desert shrubs. Soil soluble salts appear to be an important cause of community differences. Plant communities occurring on soils with the highest osmotic stress are dominated by Atriplex nuttallii. Communities dominated by Atriplex confertifolia, Sarcobatus vermiculatus, and Eurotia lanata have soils with decreasing osmotic concentrations.

An initial reconnaissance study of the site was made in July 1981, where tentative community types were identified. Representative sampling sites were then selected. Sites were sampled as follows:

1. 25 meter (80ft.) transect lines were segmented into 5 meter (16 ft.) intervals. Data were collected for each 5 meter (16 ft.) interval.
2. Points along the 25 meter (80 ft.) transect were read at 5 cm (2 in.) intervals to determine the composition of bare ground, rock, persistent and non-persistent litter, and live vegetation by species.
3. 2 X 5 decimeter (8 x 20 in.) quadrats were evaluated at 2.5 meter (8 ft.) intervals along each transect line to determine the composition of bare ground, rock, persistent and non-persistent litter, and live vegetation by species.

After collection of the field data, each community type was analyzed to determine species composition and canopy coverage. Community types were identified on the basis of dominant species. Voucher specimens were collected and dried, and photographs taken of each community type. A community type map was prepared on an aerial photograph base with a scale of 13 cm/km (8 inches per mile).

Eleven plant communities were recognized within the study area. The low species numbers and diversity are partially a result of the time of sampling which was accomplished during the month of July. The 11 plant communities are distributed from 1555 m (5,100 ft.) near the Bookcliffs to 1370 m (4,500 ft.) along the lower drainages. Along the elevational gradient, extreme erosion has been the predominant factor, influencing soils and vegetation. Some of the plant communities exist in a complex mosaic while others are much more discrete.

Abbreviated plant community descriptions follow:

1. Atriplex corrugata - greater than 10% canopy coverage.

This community is found predominantly on low shale pediments and alluvial basins of nearly level terrain with intermittent areas of thin mud flow deposits. The only species recorded in this community was Atriplex corrugata which comprise 14.6% canopy coverage. West and Ibrahim (1968) described an Atriplex corrugata community having great variability in soils. They found significant differences between sites as to exchangeable sodium percentage, thicknesses of horizons, saturation extract conductivity, and soil texture.

2. Atriplex corrugata - less than 10% canopy coverage.

The community occurs on low shale pediments, dissected shale uplands and side slopes adjacent to Atriplex corrugata community with greater than 10% coverage. This community is poorly developed with Atriplex corrugata comprising 6.7% coverage and Sphaeralcea grossulariifolia being present in trace amounts on microsites with relatively higher moisture availability.

3. Atriplex corrugata/Oryzopsis hymenoides.

The community is apparently restricted to alluvial soils with sand or sandy loam texture. Dominant species are Atriplex corrugata, Oryzopsis hymenoides and Aroshio lanata. The community may be ecotonal in nature with little or no restriction to specific soil units.

4. Atriplex corrugata/Atriplex nuttallii.

The soils associated with this community are partially derived from erosion of the pediment slopes which are basically sandy or sandy loam in texture. The community occurs on 12 to 30% slopes which are heavily dissected. The dominant species are Atriplex corrugata, Atriplex nuttallii, and Suaeda correaana. Eurotia lanata and Eriogonum inflatum are present in trace amounts.

5. Atriplex corrugata/Atriplex nuttallii/Oryzopsis hymenoides.

The soil surface of this community type has a well-developed rock pavement of calcidne and ironstone. The community occurs on alluvium such as old mud flows and/or sandy materials derived from the pediments. The dominant species include Atriplex corrugata, Atriplex nuttallii, Oryzopsis hymenoides, Eurotia lanata and Ephedra torreyana.

6. Atriplex corrugata/Atriplex canescens linearis.

The community occurs on steep, dissected upland slopes of the Mancos shale badlands. The vegetative cover occurs primarily in depressions and on the lower gradient slopes. The dominant species are Atriplex corrugata and Atriplex canescens linearis.

7. Atriplex corrugata/Atriplex canescens linearis/Atriplex nuttallii.

The community is encountered on lower shale pediments, dissected by drainage or runoff channels. Intermittent thin mud flow deposits overlie the shale. The dominant species are Atriplex corrugata, Atriplex canescens linearis, and Atriplex nuttallii.

8. Atriplex corrugata/Atriplex confertifolia/Oryzopsis hymenoides.

Remnants of old pediment surfaces, forming plateaus extending out from the Bookcliffs are dominated by this community type. The soils are derived from the Mesa Verde outwash materials and some mixing with the Mancos shale. The dominant species are Atriplex corrugata, Atriplex confertifolia and Oryzopsis hymenoides.

9. Atriplex nuttallii.

The community is associated with the sandy alluvial material on level areas and on low pediments. The dominant species are Atriplex nuttallii, Oryzopsis hymenoides, Opuntia polycnatha, Halogeton glomeratus, Gutierrezia sarothrae, Stanleya pinnata, and Sphaeralcea grossulariifolia.

10. Atriplex confertifolia/Oryzopsis hymenoides.

This community occurs on the higher pediments with coarse textured soils derived from the outwash from the Mesa Verde sandstone. Sandstone rocks and boulders comprise 33.0% of the ground cover. The dominant species are Atriplex confertifolia, Oryzopsis hymenoides, and Hilaria Jamesii.

11. Atriplex canescens/Oryzopsis hymenoides.

The community occurs in small areas on the edges of eroded pediment slopes on the western end of the plateaus. The dominant species are Atriplex canescens, Oryzopsis hymenoides, Hilaria jamesii, and Ephedra torreyana.

The successional status of the plant communities is poorly known. The communities on the steepest slopes apparently are serial stages and that is related to the erodability of the landscape at that point.

Table 5. Classification and tentative correlation of series mapped in the Book Cliffs soil survey area (from Schafer, 1981).

<u>Series Name</u>	<u>SCS Name</u>	<u>Family</u>
A		Clayey, montmorillonitic (calcareous), mesic, shallow Typic Torriorthents
B	(Bributte)	Clayey, montmorillonitic (calcareous), mesic, shallow Typic Torriorthents
C	(A)	Fine, montmorillonitic (calcareous), mesic Typic Torriorthents
D		Fine-loamy, montmorillonitic (calcareous), Typic Camborthids (vertic-like)
E	(Persago)	Loamy, mixed (calcareous), mesic, shallow Typic Torriorthents
F	(Glenton)	Coarse-loamy, mixed (calcareous), mesic Typic Torriorthents
G	(Cliffdown)	Loamy-skeletal, mixed (calcareous), mesic Typic Torriorthents
H		Fine, mixed (calcareous), mesic Typic Paleargids
I		Fine-loamy, mixed (calcareous), mesic Typic Camborthids
J		Sandy-skeletal, mixed (calcareous), mesic Typic Torriorthents
K		Coarse-loamy, mixed (calcareous), mesic Typic Torriorthents

RAINFALL SIMULATION STUDY OF WATER, SEDIMENT, AND SALT YIELDS ON THREE SOIL-LANDFORM UNITS ON MANCOS SHALE³

Background

We used the BLM large-plot rainfall simulator in the summer of 1981 to quantify relative yields of water, sediment, and salt from three soil-landform units common in the Mancos shale regions of east-central Utah. The rainfall simulator study site was located near Woodside, Utah, approximately 16 km (10 mi) northwest of Green River Utah (Fig. 2). The site was the location of the detailed soil-geomorphology study (Schafer, 1981) summarized earlier in this report.

We located plots measuring 6.1 x 6.1 m (20 x 20 ft) on 1) a low-relief shale pediment on a gray, crusted, fine, loamy shale-derived soil (soil A), and on 2) the same low-relief shale pediment on a light brown, cracked, fine, loamy aeolian soil (soil D). A larger plot encompassing a small 185 m² (2,000 ft²) microbasin was located on steep, dissected, raw shale badlands. All plots had less than 20% vegetative cover, which is representative of the region. Two simulated rainfall runs were made on each plot. Rainfall was applied at about 5 cm/hr (2 in/hr) for 35-40 minutes (approximately a 10-year, 30-minute storm for the region). Rainfall intensities were lower on the larger badland plot. Upland transects were used to quantify the relative magnitudes of rill erosion, interrill erosion, creep, and microchannel erosion on the steep badland plot.



Figure 2. Location of Rainfall Simulation Study, Woodside, Utah.

³ Detailed study results provided in Jackson and Julander (1982).

Results

Final constant infiltration rates were very low on both the gray crusted shale pediment soil and the dissected badland formation, averaging 0.3 cm/hr (0.12 in/hr) and 0.13 cm/hr (0.05 in/hr), respectively. No runoff was generated on the light brown, cracked aeolian soil.

Suspended sediment concentrations for the gray, crusted pediment soil averaged 2,000 mg/l (CV=0.25) except for a peak in concentration of approximately 5,900 mg/l (s=134 mg/l) which occurred immediately after runoff was initiated on the first run on each plot (Fig. 3). This compares to peak suspended sediment concentrations of 647,000 mg/l and 500,000 mg/l for the first and second run respectively on the dissected shale badland unit (Fig. 4). On that unit, sediment concentration generally corresponded to discharge. Roughly 80% of the sediment generated on the shale badland unit was due to rilling, 9% to cutting of tributary channels, 8% to cutting of the main channel, and 3% resulted from creep of the upper 15 cm (6 in) of the weathered shale surface.

EC in runoff (which served as an index to TDS concentration) increased an average of 35 umhos/cm (CV=0.05) on the gray, crusted, pediment soil over EC measured in the rainfall. This contrasts to an increase in EC of roughly 2,400 umhos/cm over that in the rainfall on the dissected shale badland (Figs. 5 and 6).

Conclusion

Simulated rainfall study results serve only as relative indexes of runoff, erosion and salt-producing characteristics of a site. This study suggested, however, that a similar rainfall-runoff event would produce considerably more salt and sediment from raw shale badlands than from lower-relief gray shale bottomlands. We believe that the high sediment and salt concentrations in runoff from the dissected badland unit are due to the dominance of rilling as an erosion mechanism, and the continued downcutting to salt-rich shales. The surprisingly low concentrations of sediment and salt in runoff from the gray, crusted pediment unit appears to be due to:

- 1) the erosion protection provided by the surface soil crust and mild slopes, and
- 2) less saline surface soils.

Erosion rates were apparently insufficient to expose deeper, more saline soils, and capillary processes were apparently insufficient to replenish surface salt concentrations on the gray pediment soil.

Management and control of diffuse sources of salinity in Mancos shale regions will require careful analysis of salinity sources as a function of soil-landform characteristics because of the highly variable runoff and erosion-producing attributes of different soil units.

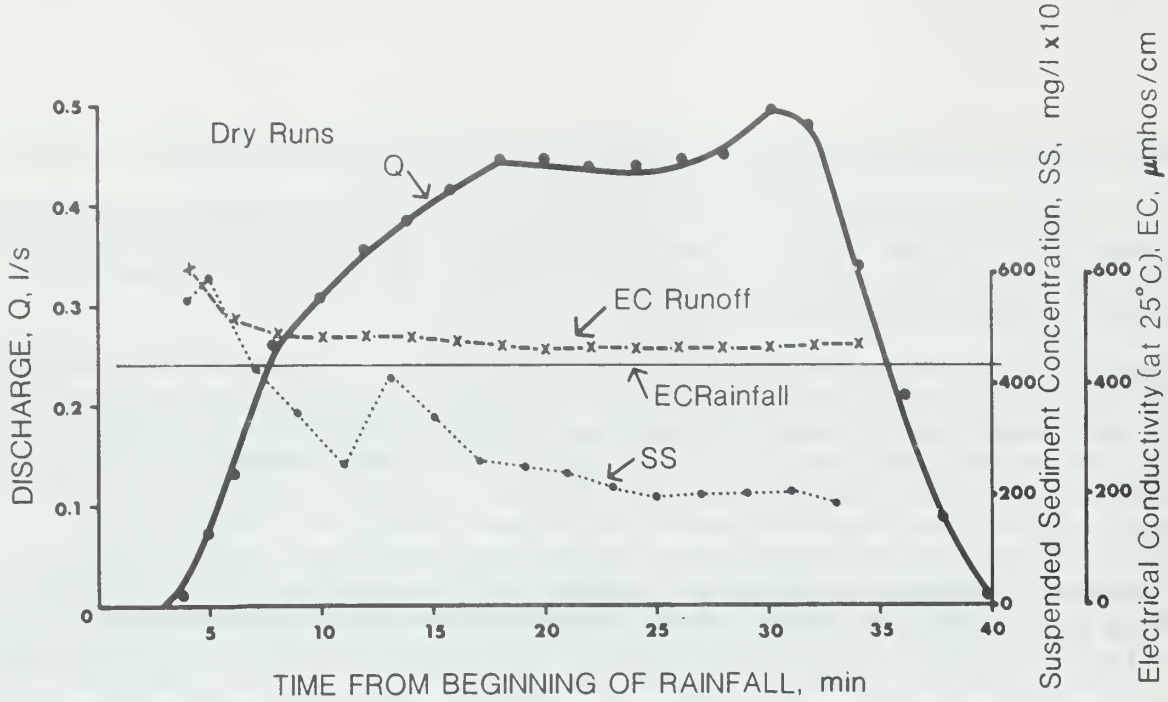


Figure 3. Average discharge, suspended sediment concentration and electrical conductivity over time for dry runs on soil A - low-relief shale pediment unit.

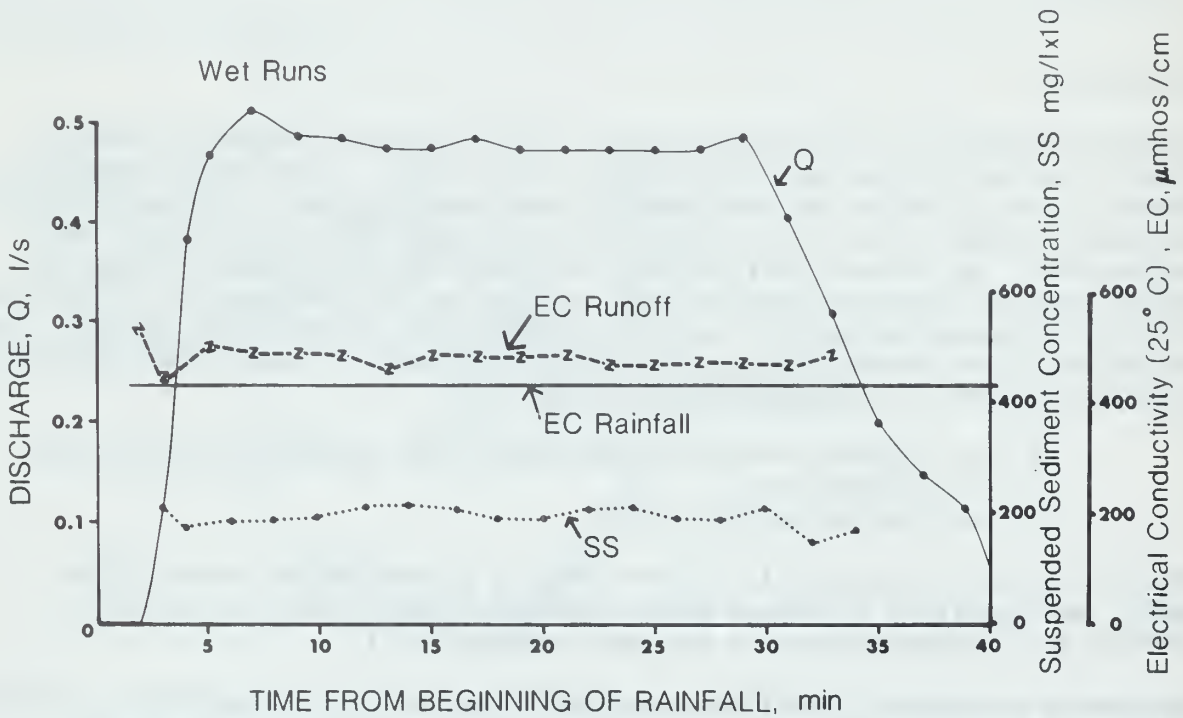


Figure 4. Average discharge, suspended sediment concentration and electrical conductivity over time for wet runs on soil A - low-relief shale pediment unit.

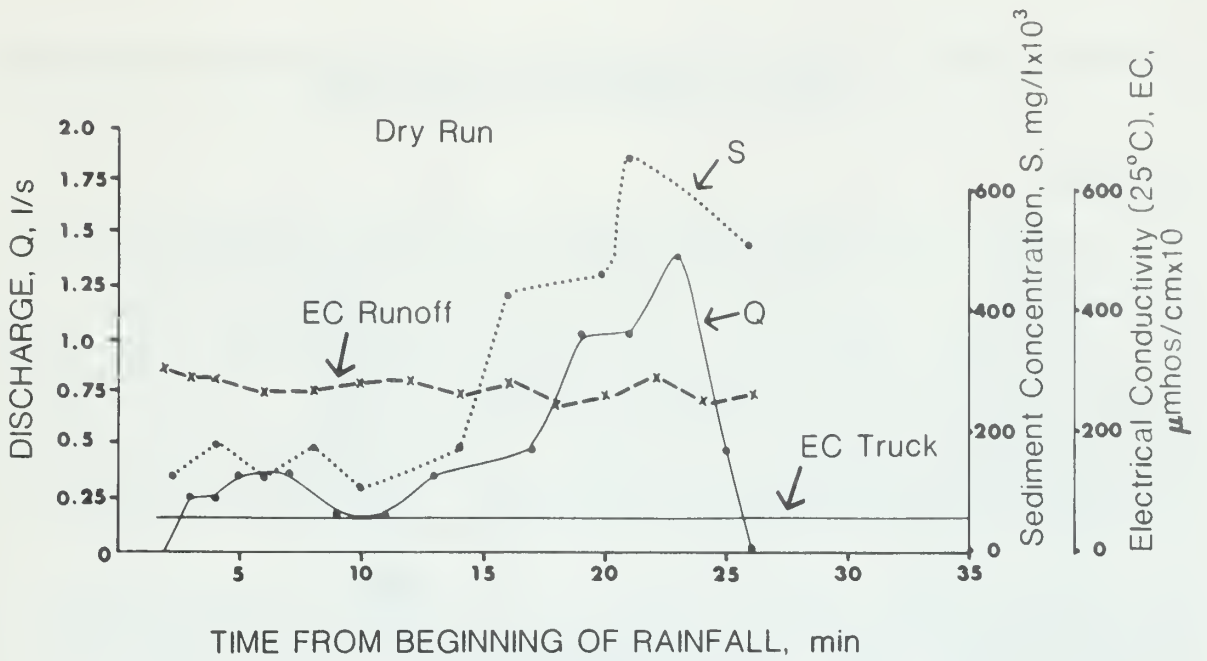


Figure 5. Discharge, sediment concentration, and electrical conductivity over time for dry runs on steep dissected Mancos shale upland.

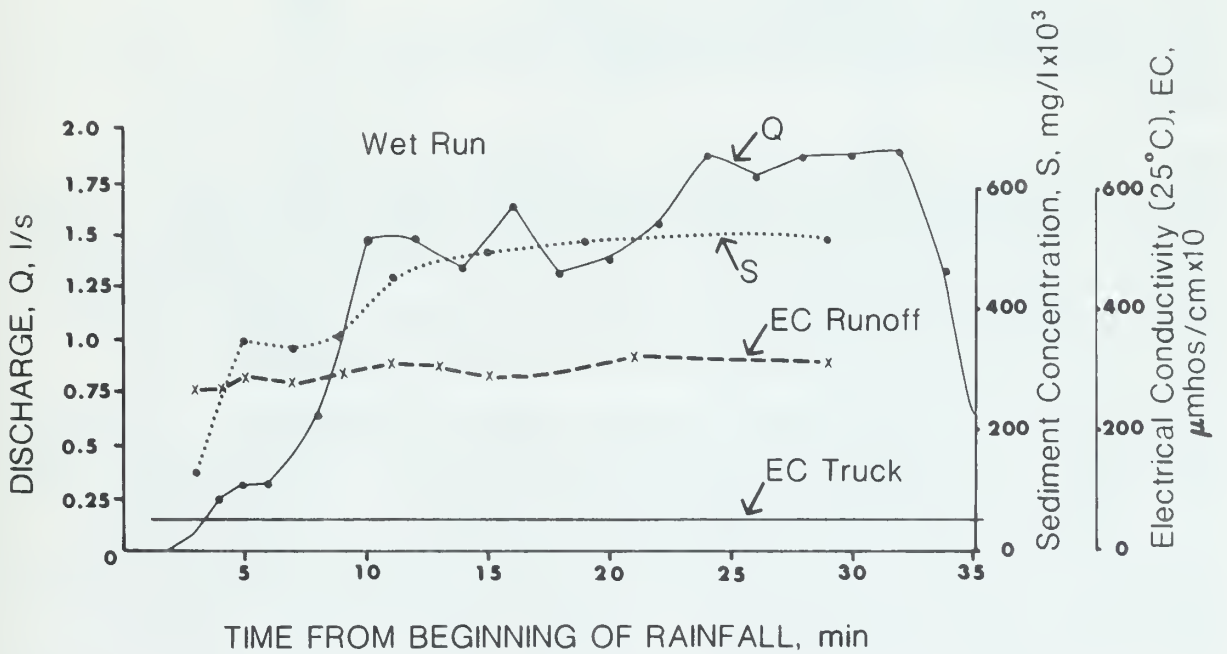


Figure 6. Discharge, sediment concentration, and electrical conductivity over time for wet runs on steep dissected Mancos shale upland.

RAINFALL SIMULATION STUDY OF THE EFFECTS OF TRAMPLING ON RUNOFF AND WATER QUALITY ON MANCOS SHALE RANGELAND⁴

Background

In the summer of 1981 a small drop-former type rainfall simulator (plot size approximately 1 m² (9 ft²)) was used to index the relative effects of vegetative cover and livestock trampling on water, sediment, and salt yields on a fine, gray, crusted Mancos shale-derived soil near Woodside, Utah (Fig. 7). The soil was described by Schafer (1981) as Soil A on a low-relief shale pediment surface and is described earlier in this report. A total of 360 runoff events were simulated on 180 plots. The experimental design involved three vegetative conditions, four levels of livestock trampling, two antecedent moisture conditions and 15 replications. Data were also collected on soil chemistry and bulk density, and runoff water chemistry.

The three vegetation conditions were: 1) mat saltbush present, 2) Nuttall's saltbush present, and 3) bare. Trampling was achieved by leading a steer across the study plots. The average intensities for minimal, moderate and excessive trampling were 8, 35 and 60%.

Rainfall was applied approximately 5-9 cm/hr (2-3 1/2 in/hr) from 1.8 m (6 ft) above the ground. Rain water was deionized prior to its application. Volumetric sampling was used to determine discharge. Electrical conductivity (EC) was measured throughout each run. Sediment was sampled from a composite of the total runoff. Data were analyzed using analysis of variance (ANOVA) for a complete multifactorial design (see Table 5).

Soil salinity at the study site is described in Table 6.

Results

The results of the ANOVA for trampling and cover are provided in Table 5. Results are depicted qualitatively in Figures 8 and 9. In general, increased levels of trampling increased the EC from 331 to 577 umhos/cm, and suspended sediment from 7,197 to 9,324 ppm in the runoff. However, increased trampling also increased infiltration and depression storage, resulting in decreased volumes of runoff from the plots. The net result was a potential decrease in total salt and sediment discharge with an increase in trampling level.

Vegetation also affected runoff and water quality from the plots. Increased vegetation cover decreased runoff volumes and salt and suspended sediment concentrations. The vegetation-trampling interaction was insignificant ($\alpha = .1$) as it affected runoff volume and suspended sediment. It was significant ($\alpha = .003$), however, as it affected salt concentrations. Vegetation cover ranged from 0 to 34% on the experimental plots. The actual range of cover on the subject rangeland site is only 5 to 10%. Realistically, this range of vegetative cover cannot be expected to greatly influence runoff, erosion or salinity yields.

⁴ Detailed study results provided in USDI (1982b).

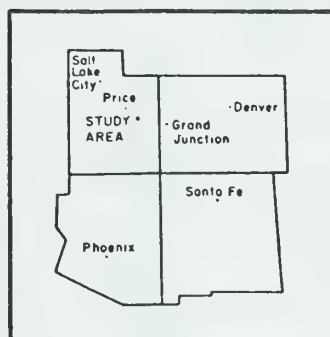
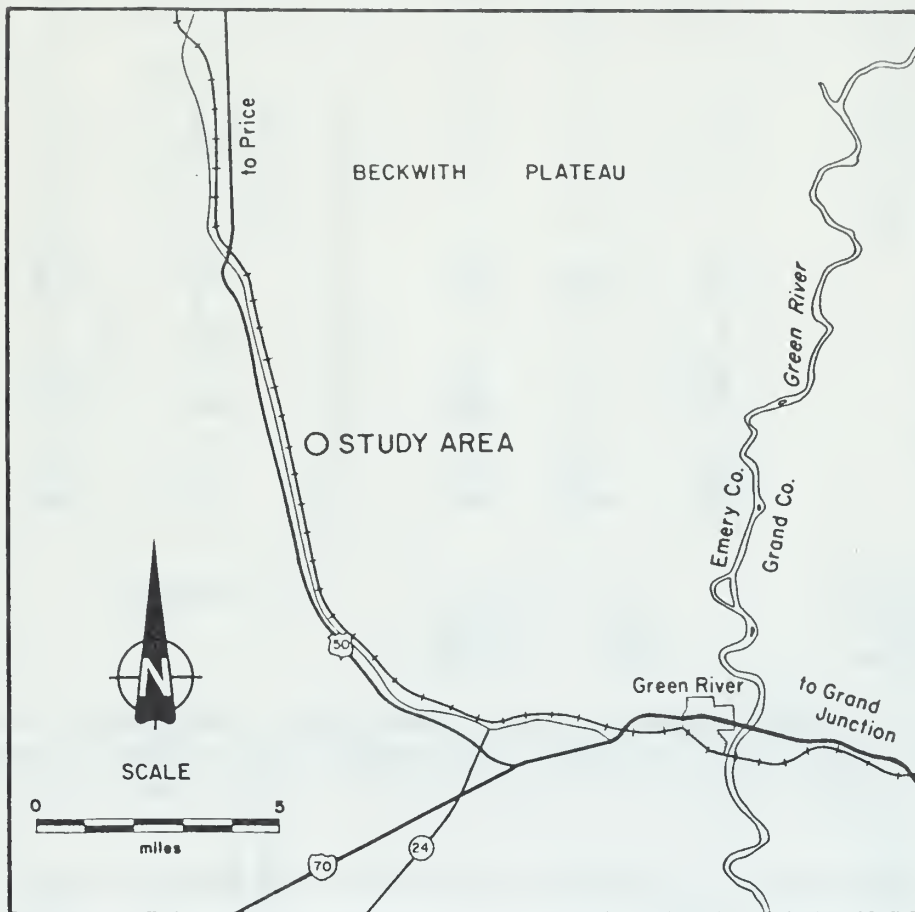


Figure 7. Location of rainfall simulation livestock trampling study.

Table 6. Summary of ANOVA Results for All Factor Field Data.

Significance Level, α , for Given Factors							
Variable	QP	NQP	VOL	EC1	EC2	INF	SED
R,T,V,M	X	X	X	X	X	X	X
R,T,V	X	X	X	.01	.003	X	X
R,T,M	X	X	X	X	X	X	X
R,T	X	X	X	INT	.001	X	.065
R,V,M	X	X	X	X	X	X	X
R,V	X	X	X	.04	.03	X	.05
R,M	X	X	X	X	X	X	X
R	VAR	VAR	.004	.01	.007	.004	.01
T,V,M	X	X	X	X	X	X	X
T,V	X	X	X	.001	.003	X	X
T,M	X	X	.03	X	X	.001	X
T	.075	X	VAR	VAR	VAR	VAR	VAR
V,M	X	X	X	X	X	X	X
V	.004	VAR	VAR	X	X	VAR	.015
M	VAR	VAR	VAR	.06	.02	VAR	VAR

R = Replication
 T = Trampling
 V = Vegetation

x = $\alpha >> 0.10$
 VAR = $\alpha << 0.001$
 INT = $\alpha << 0.001$

M = Moisture

QP = peak flow; NQP = normalized peak runoff; VOL = total runoff volume; EC1 = electrical conductivity from total field sample; EC2 = electrical conductivity from time weighted average; INF = average infiltration; SED = sediment yield.

Table 7. Analysis of soil samples taken from 0-2 cm depth at study site.

		Bare soil, n = 16	Within confines of vegetation n = 4
pH	x (mean)	7.82	8.35
	s (std. dev.)	0.05	0.10
EC	x	2.28	10.79
	s	0.39	1.85
Ca*	x	596	216
	s	82	91
Mg*	x	42	146
	s	23	44
Na*	x	46	2,260
	s	35	289
SAR	x	.48	29.6
	s	.36	2.4

*mg/liter of saturation extract

Source: Scott Fisher, USDI, Bureau of Land Management, Denver, Colo., unpublished data)

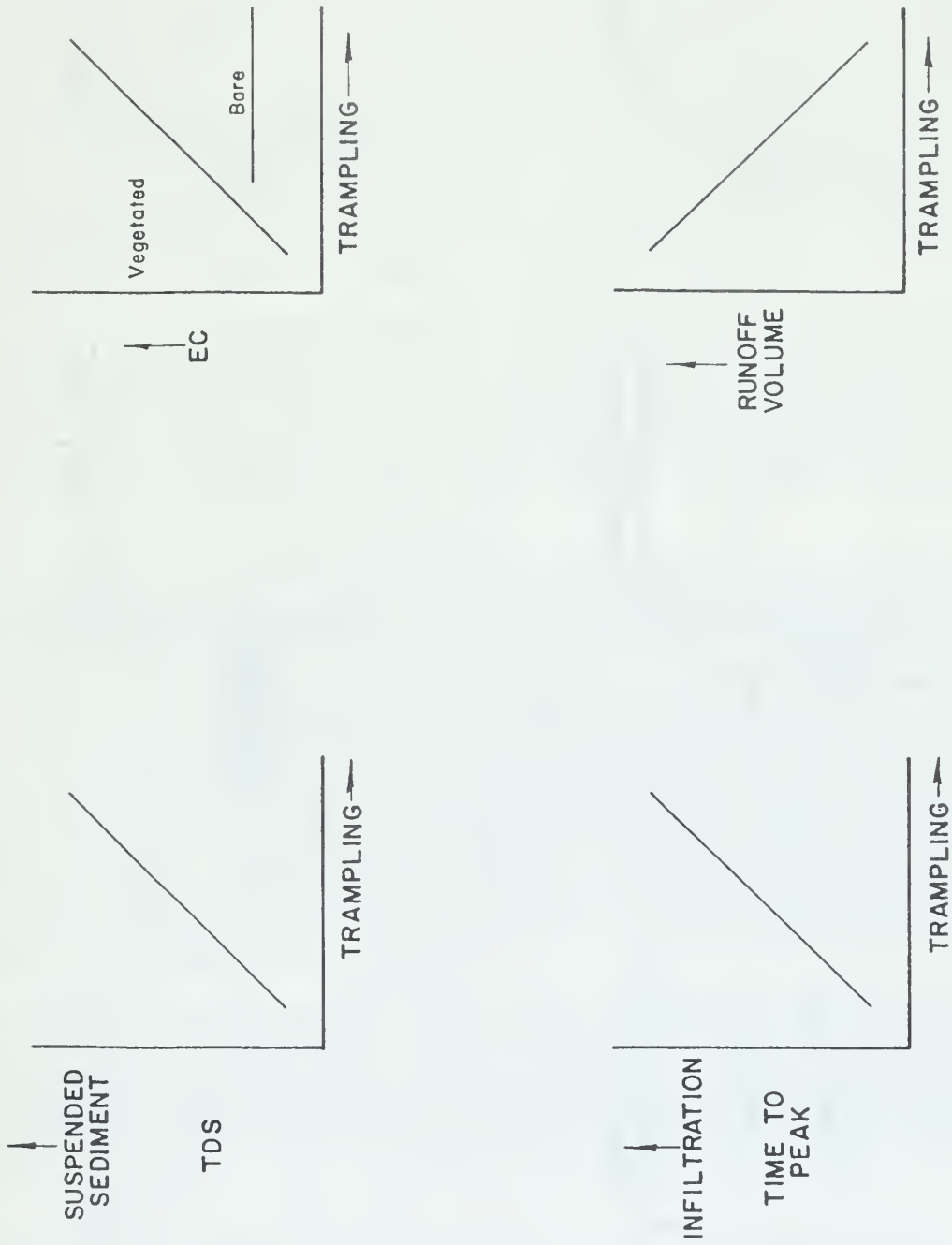


Figure 8. Qualitative relationships for significant trampling study variables.

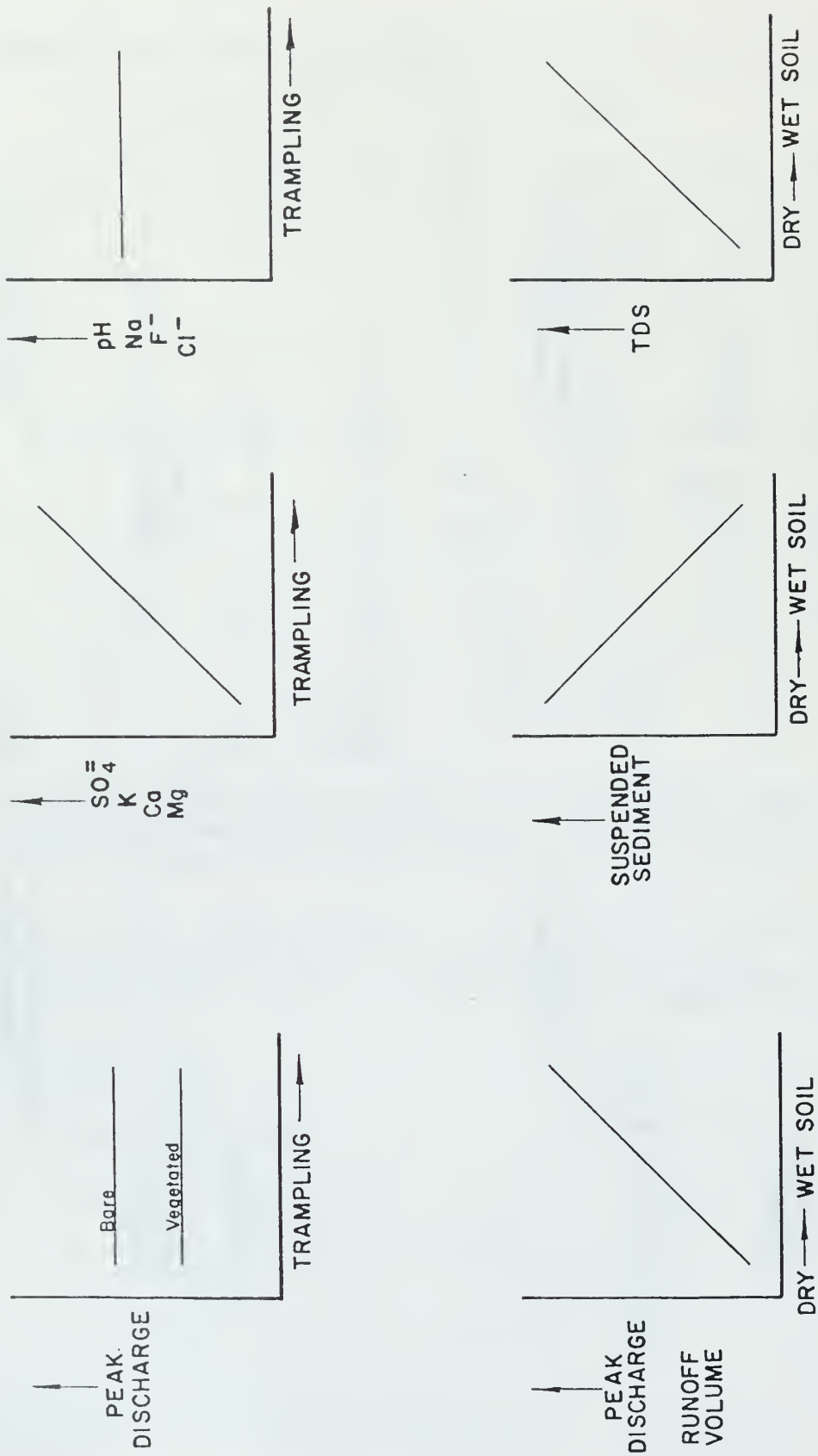


Figure 9. Qualitative relationships for other trampling study variables.

Conclusions

A number of limitations to the study results should be considered, including the experimental design, the small-plot experimental methods, and the fact that only one soil-vegetation complex was investigated. The qualitative results are more meaningful than the quantitative results. The most significant result was that trampling by livestock could potentially reduce salinity and sediment runoff from plots. This may be caused by reduced runoff resulting from increased ponding of water in surface depressions created by livestock and increased infiltration where surface crusts were pulverized. The pulverizing effects disappear after one wet-dry cycle, but the microdepressions remain. The simulated rainstorms were of higher intensity and longer duration than those encountered naturally. The proportional effects of trampling in reducing runoff were not large in the simulated storms, but would be much more pronounced for the smaller storms more common to the region.

Runoff from trampled plots had higher concentrations of sediment and salt than runoff from untrampled plots, but the reduced runoff help offset the effects on overall salt and sediment yields. The plots were trampled under dry conditions. We do not know what effect trampling under wet conditions would have on water, salt and sediment yields. Infiltration rates on the study soil are so low naturally, it is not likely that trampling under wet conditions could significantly reduce infiltration rates.

While increased vegetation cover had some influence on decreasing water, sediment, and salt yields, this generally happened at cover densities higher than those encountered naturally on the site. It was a quirk of the plot size and location that resulted in cover densities as high as 34%, where cover at the study site averaged 5 to 10%. In general, natural vegetation cover is so low at the study site there is little likelihood further reductions in cover will significantly affect runoff and water quality from these sites. While trampling intensities as high as the 60% level tested in the experiment can occur naturally on the range site represented by this study, intensities this high are rare, as livestock rarely linger in one spot due to the low levels of available forage. Realistically, trampling intensities will be much lower, and any decreases in water, salt and sediment yield due to trampling will be very small. Opportunities to manage salinity on these sites through grazing management are probably very limited.

The qualitative results of this study, when considered in the context of the study limitations, would appear applicable to the study site. While the study site is representative of much of the low-relief, saline lowlands underlain by Mancos shale in east-central Utah, it is not typical of the majority of arid and semiarid range conditions. We do not expect the results to apply to other sites.⁵

⁵ Most studies reported (e.g. Branson et al., 1981) show trampling to compact soils reduce infiltration and increase runoff.

Background

Erosion and sediment transport from surface runoff on saline shale lands have been identified elsewhere in the report as an important mechanism for salinity production. The results of rainfall simulation studies indicate that this process is particularly important on steep dissected Mancos shale badlands. The purpose of this study was to quantify long-term yields of sediment (and, by inference, salt) from unvegetated, steep dissected Mancos shale badlands. A series of gully plugs installed by BLM with bulldozers near Huntington, Utah, offered a source of sediment yield data (Fig. 10). The plugs were installed in the early 1970's to reduce flash flooding and sediment transport from Mancos shale badlands to the Huntington irrigation canal. The plugs were believed to be 100% efficient in trapping all runoff and sediments.

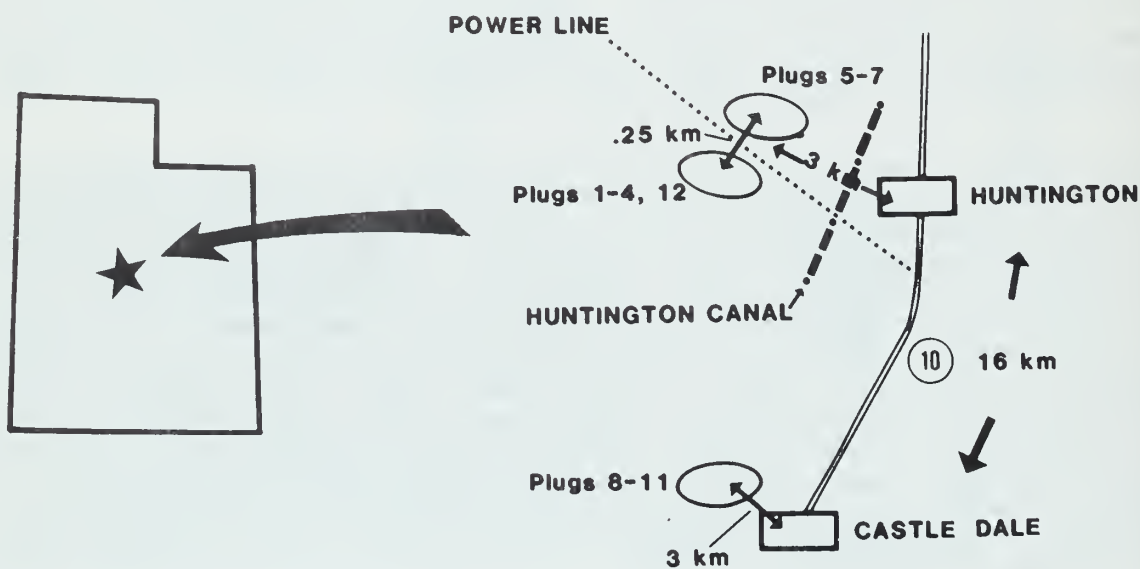


Figure 10. Location of Huntington, Utah, sediment yield study.

We selected 12 basins for study in drainages ranging from 820 to 13,000 m² (0.2-3.2 acres) in area. Numerous holes were drilled in each deposit, accumulations were mapped, and bulk densities measured. Annual precipitation data was gathered from four stations in the surrounding area (Table 7).

⁶ Detailed study results provided in Jackson and Julander (1982).

Table 8. Annual precipitation data at four stations near the Huntington sediment basins.

STATION (years record)	Hiawatha (14)	Castle Dale (15)	Ferron (15)	Price Warehouses (10)
Annual average, cm	35	17.8	20.8	20.6
Annual average during life of plugs	29.5	15.5	17.8	17.8

Results

Results of the sediment basin study are provided in Table 8. Sediment accumulations in the retention plugs averaged 7.75 t/ha/yr (3.4 tons/acre/yr). The highest sediment accumulation was from the steepest basin. However, sediment accumulations did not correlate well with any of the measured watershed characteristics. Annual precipitation during the 6-7 year life of the plugs as measured at nearby stations was not significantly different ($\alpha = 0.05$) from the long-term average for the area (20.1 cm)(Table 7).

Mancos shale sediments yield roughly 30 kg of salt per metric ton (t) of sediment (a 3% salt content in sediments)(USDI, 1978). Thus, the estimated average annual salt yield from the study basins was 0.23 t/ha/yr (0.10 tons/acre/yr).

Conclusions

Six to seven years are not long enough to accurately determine long-term sediment and salt yields from shale badlands in arid settings. Large, infrequent storm events can cause a disproportionately high rate of erosion. However, the average annual sediment yield--7.75 t/ha/yr (3.4 tons/acre/yr)-- and salt yield--0.23 t/ha/yr (0.10 tons/acre/yr)--represent a reasonable estimate of long-term salt and sediment yields from Mancos shale badlands in arid environments. The values compare favorably to sediment and salinity yield estimates calculated for other regions on Mancos shale. Salt yields are roughly two times higher than those estimated at Badger Wash, Colorado. This is expected, however, because study basins at Badger Wash are less saline, less steep and more vegetated than those at Huntington. Sediment yields at Huntington are roughly 70% higher than those determined by the Soil Conservation Service (SCS) (USDA Soil Conservation Service, unpublished data) for five small basins at Indian Wash, Colorado. Again, the Indian Wash basins have milder slopes than those at Huntington and could be expected to produce somewhat less sediment (Table 9).

In another unpublished report, SCS estimates erosion from steep Mancos shale badlands to be 20 to 34 t/ha/yr (9 to 15 tons/acre/yr). This is higher than that measured at Huntington but, presumably, was determined in part from data that contained a large, infrequent storm which contributed a large proportion of the total erosion.

Table 9. Watershed characteristics and sediment yields, Huntington sediment basin survey.

Plug No.	Drainage Area (m ²)	Plug Age (yrs)	Total Relief (m)	Weighted Watershed Slope (%)	Average Channel Slope (%)	Weighted Channel Slope (%)	Volume Sediment (m ³)	Sediment Yield (t/ha/yr)
1	3,720	7	37	47	18	14	13	7.81
2	6,970	7	42	41	12	12	35	11.22
3	13,000	7	62	54	23	21	49	8.37
4	7,150	7	41	45	19	18	29	9.11
5	2,410	6	32	55	33	32	9	10.04
6	2,230	6	30	53	18	18	10	11.90
7	2,690	6	37	59	25	25	15	14.76
8	1,000	6	27	58	33	32	1.0	2.67
9	820	6	16	34	22	18	1.3	3.97
10	1,610	6	16	36	23	20	1.9	3.10
11	1,300	6	10	18	10	10	0.7	1.49
12	910	7	7	20	13	12	3.9	9.49
X	3,650	6.4	30	43	21	19	14	7.81
S	3,660	0.5	16	14	7.4	7.3	16	4.15+

X = mean, S = standard deviation

Table 10. Reservoir sediment data summary at Indian Wash, Colorado (from USDA Soil Conservation Service, unpublished data).

Retention Structure	Drainage Area (mi ²)	Slope (deg.)	Average Annual Sediment Deposition (ac-ft/mi ²) (9 yrs)	Sediment Deposition (tons/ac/yr)
Chippewa	0.24	3.27	0.56	1.69
Cheyenne	0.22	2.67	0.58	1.75
Choctaw	1.12	11.30	1.16	3.51
Cherokee	0.31	1.55	0.29	0.88
Creek	0.40	6.37	0.70	2.12
				1.99 = x
				0.96 = s

In general, very rough estimates of long-term erosion rates in Mancos shale range from less than 2.3 t/ha/yr (1 ton/ac/yr) on less steep, moderately vegetated sites to somewhere between 7.2 and 34 t/ha/yr (3.4 to 15 tons/acre/yr) on steep unvegetated dissected Mancos shale badlands. Salinity yields are roughly 3% of the sediment yields.

BASEFLOW SALT YIELDS ON SMALL STREAMS IN THE PRICE RIVER BASIN, UTAH⁷

Background

Concurrent with the study of summer storm runoff on ephemeral washes in the Price River Basin which is described elsewhere in this report, weekly monitoring of discharge and salinity was also conducted at five intermittent stream sites and 13 perennial stream sites in the Price River Basin (Fig. 11). The purpose of the monitoring study was to determine average water quality as indexed by EC of baseflows, and to contrast the relative importance of salt loading from baseflows with that from storm runoff. Also provided is an analysis of the baseflow contribution of Desert Seep Wash to the total salt load on the Price River at Woodside, Utah.

The 18 sites selected for monitoring covered the following tributary streams of the Price River: Gordon Creek, Miller Creek, Coal Creek, Soldier Creek, Marsing Wash, Washboard Wash, and Icelander Creek (Fig. 11). These streams represent all the major tributaries of the basin. The selected streams all traverse major Mancos shale areas in the basin.

For the ten-week study period, monitoring of baseflows at these sites was interrupted by extensive storm runoff during early October. However, there are sufficient data to estimate average baseflow discharge and EC values from the data collected in September and late October.

Results

Results of the baseflow monitoring program are provided in Table 10.

Table 11: Ranking of estimated baseflow discharge and salt delivery rate among the monitored sites.

Station ID	Estimated Baseflow , Salt Delivery Rate 1,000 t/year	Estimated Baseflow Runoff, m ³ s ⁻¹
18 Marsing Wash	71	0.85
17 Washboard Wash	22	0.28
3 Coal Creek at Hwy 6	8	0.06
13 Miller Creek at Hwy 10	3	0.06
2 Lower Gordon Creek	3	0.06
15 Icelander Creek at Hwy 6	2	0.03
11 Lower Soldier Creek	2	0.03

⁷ Detailed study results provided in USDI (1982a).

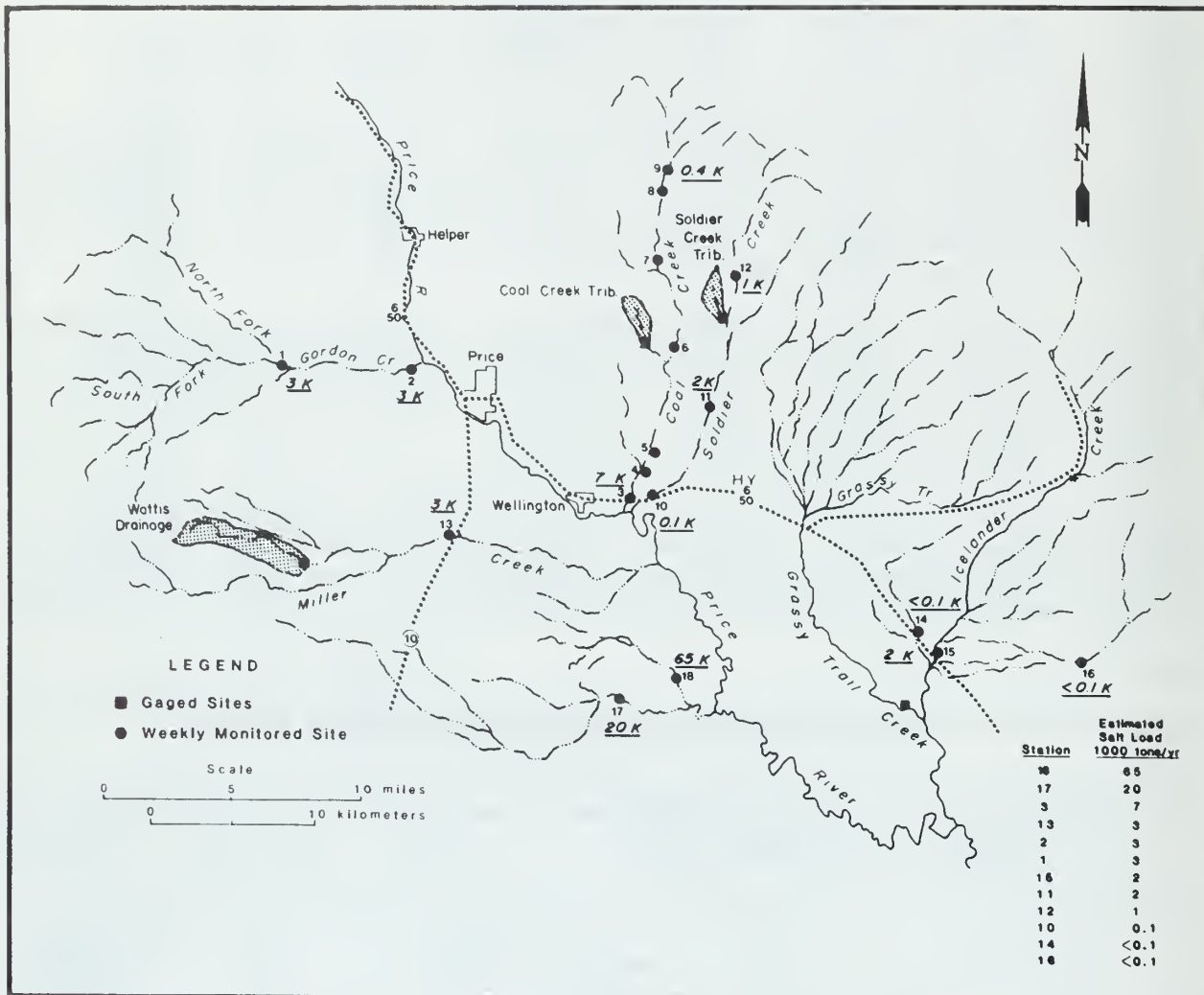


Figure 11. Location and estimated baseflow salt loads of selected stations in the Price River Basin, Utah.

Table 10 shows that Marsing and Washboard Washes delivered salts at an estimated rate of 93,000 t/yr during the study period. These baseflows are associated with irrigation return flows in the area. At least part of the flow originates from the Carbon and the Huntington-Cleveland Canals. Marsing Wash and Washboard Wash are both major tributaries of the Desert Seep Wash; the latter has had a gaging station (09314280) since 1973.

Although discharge records at Desert Seep Wash station have been maintained by USGS since 1973, no historic records of EC are available. To estimate salt load from Desert Seep Wash, EC values were monitored at Marsing Wash and Washboard Wash. EC readings ranged from 3,000 to 4,000 micro-mhos/cm. If an average EC is taken at 3,500 micro-mhos/cm, an average TDS is estimated at 2,800 mg/l.

Applying the 2,800 mg/l average TDS to the baseflow records at station 09314280, an average annual salt load at the station since 1973 is estimated at 62,300 tons. A tabulation of annual salt loads is shown in Table 11. For comparison annual salt loads at Woodside station are also shown. The total salt load at Woodside includes both baseflow and storm salt loads. Table 11 shows that baseflow at Desert Seep Wash contributes about 1/4 - 1/3 of the total salt load at Woodside station.

Table 12: Estimates of Baseflow Salt Load at Desert Seep Wash (09314280) and Salt Load at Woodside (09314500)

Water Year	Baseflow Volume (09314280) $10^6 \text{m}^3 \text{yr}^{-1}$	Baseflow Salt Load t/yr	Total Salt Load at Woodside t/yr
1973	24.59	83,500	374,000
1974	14.58	49,500	171,400
1975	25.40	86,200	238,500
1976	18.46	62,700	182,400
1977	7.30	24,700	47,400
1978	9.16	31,100	131,600
1979	16.54	56,200	NA
1980	27.61	93,700	NA
1981	21.45	72,800	NA
Mean	18.35	62,300	
Standard Deviation	7.14	24,200	

Thirty episodes of major summer and fall thunderstorms were identified from the runoff records for the Price River at Woodside. Total salt load contributed by runoff related to these storms (excluding baseflows) is 218,000 tons for the 10-year period of analysis (1969-1978). This represents over 11 percent of the total salt load during the same period at Woodside and is less than 1/3 the baseflow salt contribution from Desert Seep Wash.

Conclusions

The study results indicate that baseflows from groundwater sources and irrigation return flows in the Price River Basin contribute over three times the annual salt load in the Price River at Woodside, Utah, than does the surface runoff from short-duration summer convectional storms.

The long-term trends (11-month moving averages) of baseflow at the Desert Seep Wash gaging station are not related to the long-term trends of flow diversion at the Carbon Canal. This suggests basin-wide groundwater condition may possibly determine the trend of baseflow condition at that station. The moving averages of baseflow at the station were shown to be partly related to the winter precipitation on the basin.

The short-term (month-to-month) fluctuations of baseflow at the Desert Seep Wash station were related to the monthly variation of flow diversion at the Carbon Canal. Our cross-correlation analysis indicates that it takes about 50 days for the diverted water to percolate, seep and finally reach Desert Seep Wash.

SALT YIELDS ASSOCIATED WITH THE DEVELOPMENT OF A RIPARIAN-TYPE WILDLIFE MANAGEMENT AREA⁸

Background

Part of the plan to reduce salinity in the Uinta Basin Unit of the Colorado River Water Quality Improvement Program is to line irrigation canals (USDA, 1982). This action results in a reduction of riparian-type habitat as water losses from canals to adjacent soils are reduced. BLM was asked by the Bureau of Reclamation to explore the feasibility of expanding the BLM wildlife management area at Pariette Draw near Vernal, Utah (Fig. 12) (USDI, 1981) to compensate for expected wildlife habitat losses due to the lining of irrigation canals. The Bureau of Reclamation wanted BLM to demonstrate that expansion of the wildlife management area would not significantly reduce the expected salinity benefits from the canal lining program. The purpose of this study was, therefore, to analyze available hydrologic and water quality data, collected both before and after construction of the Pariette Draw Wildlife Management Area, to quantify the effects, to date, of the wildlife area on salinity. While BLM does not operate a large number of wildlife areas, restoration and reirrigation of former riparian zones is an important objective of the Bureau's soil and water program, and fisheries and wildlife programs.

Pariette Draw is located 10 km (6 mi) downstream from Ouray, Utah. Mean annual discharge is $2.03 \times 10^7 \text{ m}^3 \text{ yr}^{-1}$ (16,500 acre-ft/yr). Saline shale members of the Uinta formation outcrop in much of the lower basin. Development of the original wildlife area began in 1977. Operation began the following year. Daily pre-treatment water data was collected upstream (Station 09307200) and downstream (Station 09307300) of the project site from 1975-77. Post-treatment data was collected from 1977-1981. Pre- and post-treatment monthly water data was collected at a third station (09307250). A modified version of the QWSALT computer program (Hudson et al., 1982) was used to calculate daily, monthly and annual salt loading data and salt-water discharge relationships. We used T-tests to identify differences in water discharge and salt yield between periods (pre- vs. post-project) at individual stations and between stations within individual periods. Separate power functions were used to describe the salt loading function (total dissolved solids, TDS, vs. discharge, Q) for each station both pre- and post-project. F statistics were used to test for differences in salt loading functions.

⁸ Detailed study results provided in Jackson and Hudson (1983)).

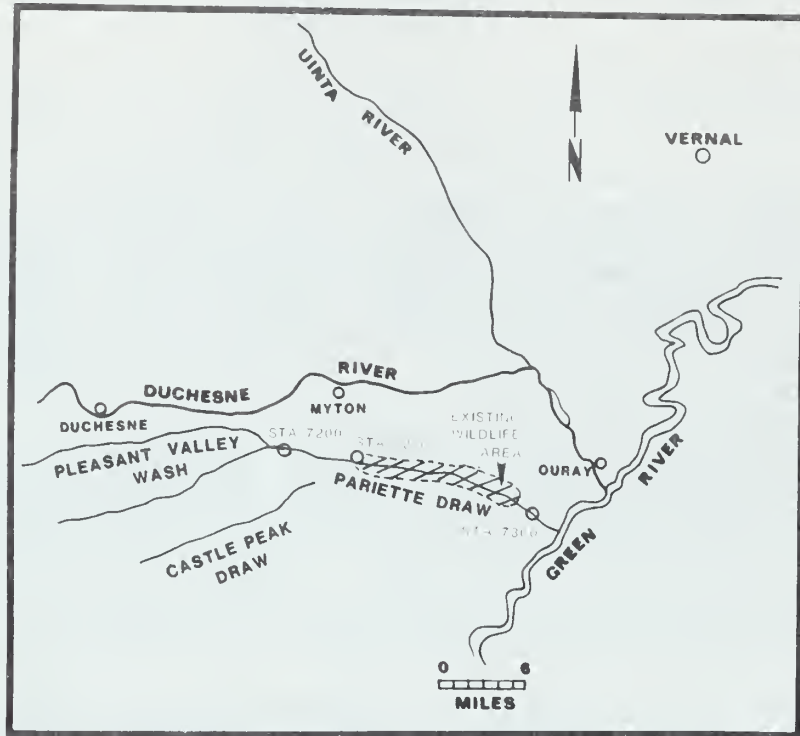


Figure 12. Location map, Pariette Draw, Utah.

Results

We recorded a 50% increase in annual salt yield at the downstream (7300) gage at Pariette Draw following the beginning of construction of the Pariette Draw Wildlife Management Area (Table 12). This increase occurred during a period when there was a much smaller (11%) increase in salt yield at the upstream (7200) station. However, analysis of water discharge data and station salt-loading functions (Q vs. TDS) indicate that 94% of the increase in annual salt yield at the downstream station is due to the increase in mean monthly flow following the beginning of construction of the wildlife management area, and 6% of the increase is due to a small though statistically significant ($\alpha = 0.05$) change in the salt loading function (Q vs. TDS) at the downstream station (Fig. 13). We hypothesize that increased inflows from Castle Peak tributary caused downstream flows during the post-construction period to increase proportionally more than flows entering the area upstream.

Table 13. Differences in mean monthly discharge, Q ($m^3 \times 10^6$) and salt (t) between periods within stations, and between stations within periods.

Period	Variable	Station		Difference (α)
		7200	7300	
Pre-	Q	1.67	1.14	0.53 (0.000)
	Salt	3,656	2,661	995 (0.000)
Post	Q	1.98	1.74	0.24 (0.004)
	Salt	4,068	3,985	83 (0.664)*
Difference (α)	Q	0.31	0.60	
		(0.287)	(0.048)	
	Salt	412	1,324	
		(0.232)*	(0.020)	

*No difference

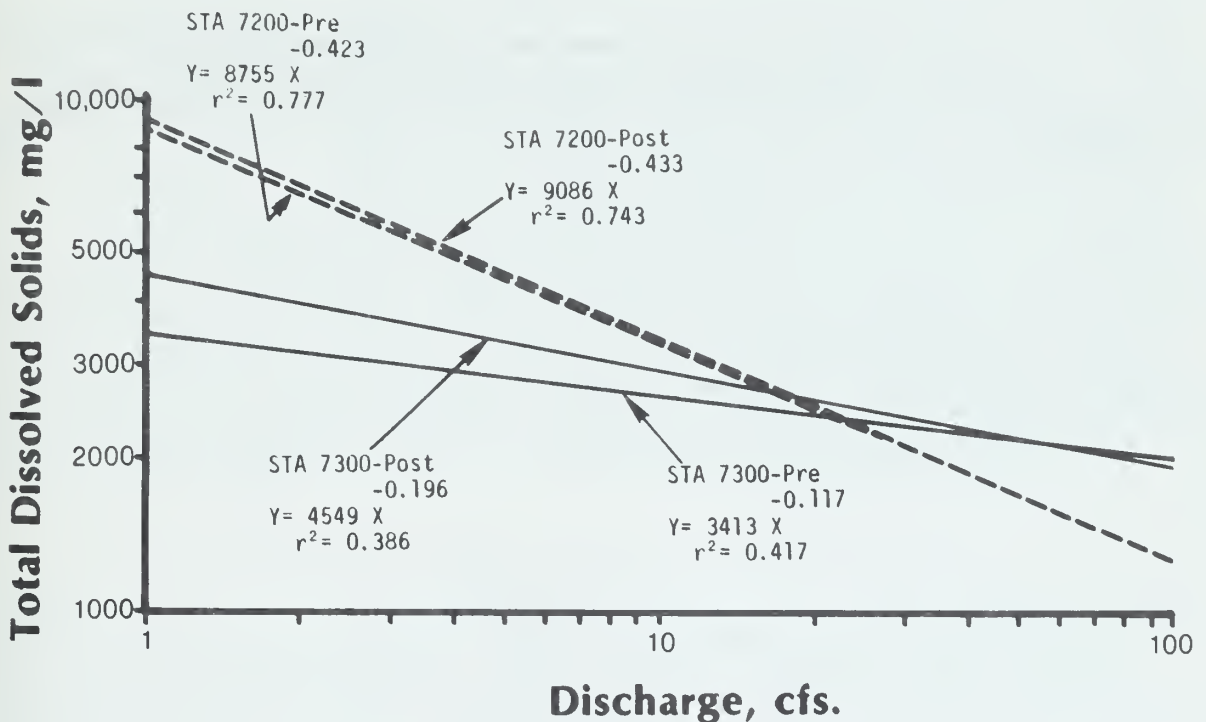


Figure 13. Relationship between discharge (X axis) and total dissolved solids concentration (Y axis) for gaging stations 7200 and 7300 for pre-project (1975-76) and post-project (1977-81) periods.

Conclusions

Based on the analysis of the existing data at Pariette Draw, we believe that a 300-ha (740-acre) expansion of the wildlife management area will result in a maximum increase of approximately 540 to 630 t (600 to 700 tons) of salt per year in the Colorado River (based upon an increase of $1.97 \text{ t ha}^{-1}/\text{yr}^{-1}$ ($0.86 \text{ tons/acre/yr}$) at the existing wildlife area). We predict approximately $7.7 \times 10^6 \text{ m}^3 \text{ yr}^{-1}$ (6240 acre-ft/yr) of water will be consumed by the wildlife management area.

Because the 6-year period of record is short for this type of analysis, any results or conclusions must be considered tentative. Four factors should be considered in analyzing the impact of this type of development on salt yield:

1. The increase should be greatest during the first few years following construction-when new salt sources are first exposed and put in contact with water.
2. Future increases due to expansion of the area can be partly mitigated by avoiding development of saline shale sites.
3. Some mitigation could occur by altering or eliminating the operation of the management area during the September high-flow period
4. Operation could be altered so as to reduce the water flow-through time, reducing contact time with salt sources.

In general, as formerly dry soils are irrigated in the riparian zone restoration project, some quantity of dissolved material will be released from those soils. In most cases those impacts to water quality should be fairly small and should be weighed against benefits from reduced erosion, and to fisheries and wildlife.

IV. SALT YIELDS FROM SURFACE RUNOFF: MANAGEMENT ALTERNATIVES

INTRODUCTION

The 1978-79 Salinity Status Report (USDI, 1980) suggested that site-specific analysis is required to quantify opportunities for managing salinity from surface runoff. General guidance was provided for the management of livestock use on three categories of rangeland: 1) nonsaline-slightly saline lands, 2) moderately saline lands, and 3) highly saline lands. A classification of rangeland soils by salinity class is provided in the 1977 Salinity Status Report (USDI, 1978). Studies reviewed above (and in Hawkins, et al., 1977) suggest a close relationship between salt and sediment loads in surface runoff. Therefore, the management of salinity in surface runoff from saline lands is closely related to the management of lands for runoff and erosion.

In general, salinity is not a major issue in the management of livestock grazing on nonsaline to slightly saline lands. On these lands, good management for forage production, range, and watershed condition will provide good management for salinity.

Salinity can be an issue on moderately saline lands if management results in large increases in surface runoff and erosion. Generally, however, grazing at light to moderate levels, in accordance with a system of use and rest designed to provide sufficient vegetative cover to maintain erosion stability, will limit salinity levels in runoff.

On highly saline lands, options for managing salinity through grazing management are limited. Vegetative cover is usually very sparse, and changes in cover are not likely to be great enough to significantly affect runoff and erosion condition. Trampling may result in changes in soil properties which will either increase or decrease water, sediment and salt yields. Trampling gray, crusted, relatively impermeable saline shale soils may actually increase infiltration and depression storage and reduce salt and sediment yields. More permeable, structured shale soils may, after trampling, become more compact and less permeable and result in higher yields of water, sediment and salt. While trampling intensities on such sparsely vegetated range sites are rarely sufficient to cause major changes in runoff and erosion, management should consider various possibilities of impacting salt and sediment yields on a site-specific basis.

Land Treatment and Structural Alternatives

In most cases, grazing management which results in good plant production and adequate cover for protection of soil from excessive runoff and erosion will also provide salinity benefits. There are areas, however, where existing watershed condition is poor--either naturally or because of poor historic management--which contribute excessive amounts of salt and sediment in surface runoff. In these situations, land treatment and structural alternatives--such as furrows, retention structures and gully and headcut controls--are available and can result in:

1. Significant reductions in runoff, erosion and salt yields.
2. Increased gully and channel stability.
3. Improved soil-water conditions for production of livestock forage and plants for wildlife with improved watershed condition.
4. On-site water for livestock and wildlife.
5. Decreases in downstream erosion and channel instability.

In general there is a different relationship between probable salinity benefits and related multiple benefits resulting from watershed treatments in each of the three salinity classes. On nonsaline to slightly saline soils, treatments to reduce or contain runoff and improve infiltration will result in very small salinity benefits on a per-acre basis. However, benefits due to reduced erosion and increased soil moisture are likely to be comparatively large. If good watershed condition can be achieved, it may be sustained by proper land use management without further maintenance of structures. On these sites, the primary benefit of land treatments is to increase the rate of recovery of watershed condition over that which could occur without the use of treatments.

On highly saline soils, retention structures such as trenches, dikes, or retention dams will provide large salinity and sediment benefits on a per-acre basis. However, on-site vegetation response to improved soil-water conditions will often be comparatively small.

Moderately saline soils will usually respond to watershed treatments by providing a more balanced mix of benefits to both salinity and on-site range condition than either the nonsaline to slightly saline sites or the highly saline sites. Salinity benefits will be less than those obtained on highly saline sites, but greater than those realized on non to slightly saline sites (Fig. 14). Conversely, on-site benefits to plant production will likely be greater than those realized on highly saline sites, and less than those realized on non to slightly saline sites. Benefits related to reduced erosion, reduced downstream flood impacts, on-site water supply and wildlife can be realized on moderately saline soils. Again, analysis of potential benefits will have to be made on a case-by-case basis and consider such factors as soils, landform, hydrology, climate, existing range and watershed condition and potential, and relevant downstream values. The next section provides more detail on specific watershed management techniques which may provide benefits to salinity.

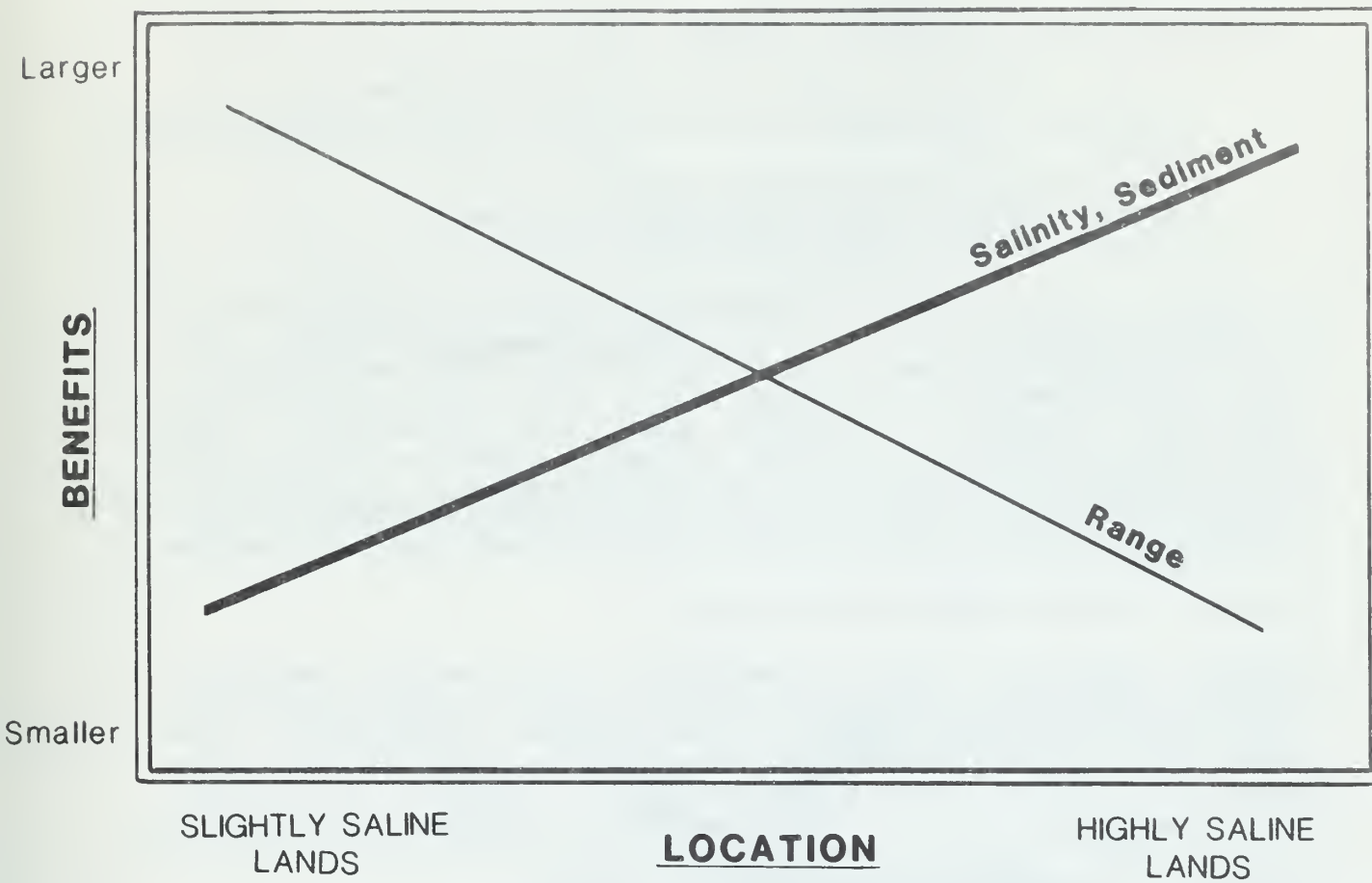


Figure 14. Conceptual depiction of benefit trade-off resulting from watershed management on nonsaline to highly saline lands.

LAND TREATMENT AND STRUCTURAL CONTROL TECHNIQUES

Introduction

Four diffuse sources of salt are considered in this section.

1. Perennial flow from slightly saline cliffs and uplands which then traverses saline lowland formations, both as channel flow and groundwater.
2. Active gullies in saline shale sediments
3. Surface erosion of steep shale badland formations
4. Surface erosion of saline rangelands

The purpose of this section is to describe possible structures and procedures to reduce salt delivery from each of the above sources, and provide an overview of technologies believed to be effective in the control of salinity. Important considerations are discussed as they relate to the design of individual control structures. We recognize, however, that the analysis of individual salinity problems and the design of specific control programs will have to be performed by field specialists on a case-by-case basis. In general, diffuse source control includes vegetation and watershed management, land treatments and selective withdrawal and disposal of poor quality streamflows.

Perennial Flow From Slightly Saline Uplands

Perennial streams from slightly to moderately saline formations (sandstone, dolomite, conglomerate, etc.) such as the Book Cliffs in Utah and Colorado produce water with salt concentrations generally less than 500 mg/l. These streams originate from snowmelt and groundwater. They then traverse lowland marine shale deposits. Subsurface channel flow is perennial. Salt concentrations measured in surface flows in channels cut in marine shales increase to an approximate level of 2,500 mg/l depending on the length of channels and time water is in contact with salt-bearing sediments.

To effect a reduction in salt pickup from saline lowlands, it is necessary to eliminate surface and subsurface water contact with channel soils. A concrete cutoff wall located in the mouth of a canyon just above contact with marine sediments will stop base streamflow. The wall must be on an impermeable layer, either bedrock or tight clay layer (Fig. 15). The depth of permeable soils will generally be least just upstream from the mouth of a canyon. A pit filled with gravel located just upstream from the cutoff wall will facilitate collection of streamflow. A pipeline can be constructed from the gravel sump down to the river (Fig. 16). High quality water would then be sent to the river by gravity without coming in contact with saline soils. Such a pipeline could also provide water for livestock and wildlife at little extra cost and with only a small reduction in the amount of water delivered to the river (Fig. 16). Pipe diameter would be a function of the highest flow expected from stable winter groundwater discharge. It is not practical to attempt to collect water from short duration, high velocity surface runoff events.

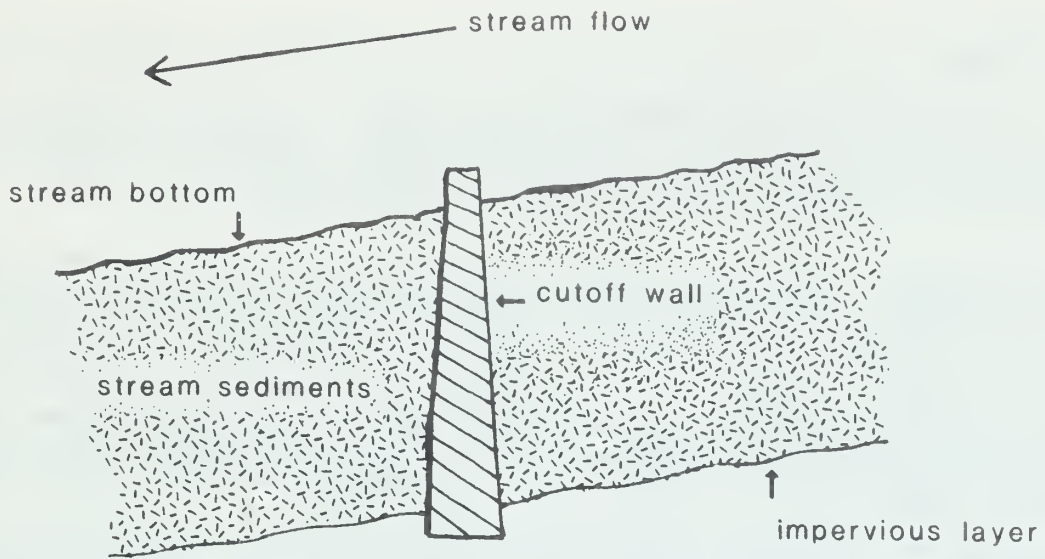


Figure 15. Side view of concrete cutoff wall.

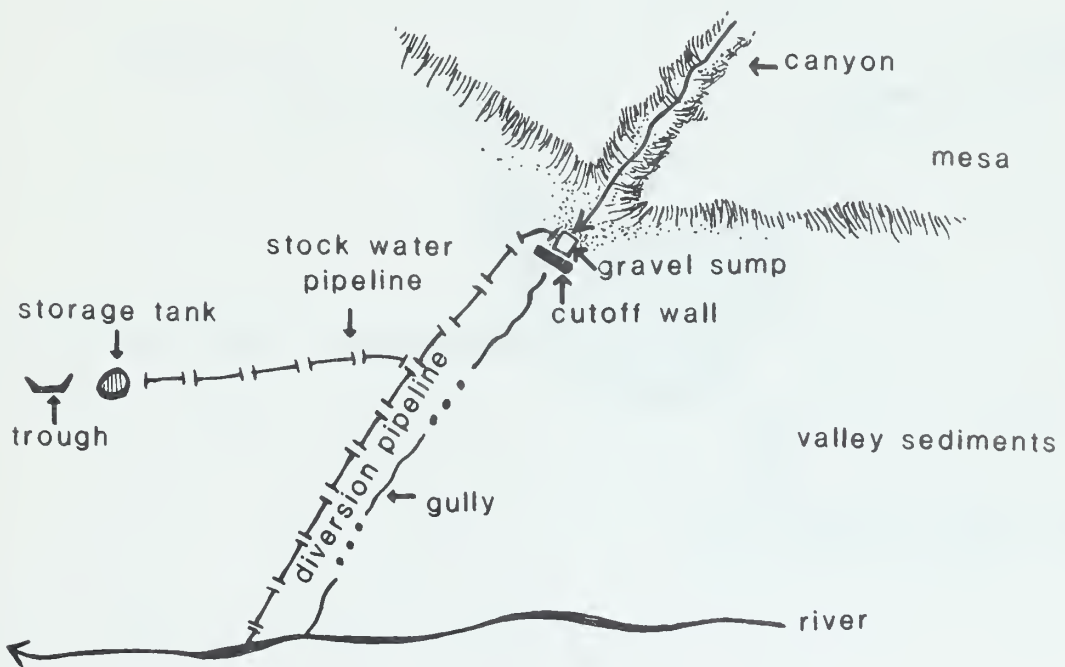


Figure 16. Pipeline diversion and livestock water facilities.

Gully Erosion

Gullies cut through saline sediments are a source of sediment and salt from rangelands. This is especially true when gullies are actively degrading or advancing in a headward direction. Aggrading gully systems serve as a repository or storage for sediment eroded from upstream.

Because the source of salts from gully systems is associated with bed and bank materials, gully control can only be effective if it arrests gully deepening or headward advance. A gully control structure for salinity control is successful only when it stabilizes the gully and eliminates salt contributions from bed and bank materials. The structures do not serve to effectively trap large quantities of salts. Therefore, many gully systems which are no longer active are not amenable to management for salinity control even though other watershed benefits may be derived by healing gullies.

The process of degradation can be reversed by artificially raising the level of a gully bottom at its mouth and by protecting nick points throughout the gully system (Heede, 1981). A gully plug properly constructed at the lower end of a gully system can cause sediments to be deposited behind the plug (dam) and at an elevation up channel several times higher than that of the dam. Nick points must be armored with rock, rip-rap, gabions, etc., so no further cutting can occur.

The top of a gully plug should not be raised above the level of surrounding uplands. This would cause flows to go around the plug creating a new channel parallel to the old one. A gully plug should be constructed low enough in the gully to allow flash floods to overtop it. It can be constructed from compacted earth fill or rocks. Heede (1976) gives specifications, design drawings, and important considerations necessary for constructing gully plugs.

A gully plug should require little maintenance when properly constructed. There is no requirement to remove sediment from behind dams. The purpose of the structures is to hold initially trapped sediment behind the dams indefinitely, thus lowering the gradient and erosion potential upstream.

The plug should also have a properly designed and constructed spillway to concentrate flow where it can be controlled. The spillway is generally located in the center of the plug. The plug should be set into the bottom of the gully by means of a core trench and the ends of the plug should be keyed into the sides of the gully (Fig. 17). The spillway should be armored to protect the structure from erosive forces of swiftly flowing water. Concrete or rip-rap can be used (Fig. 18).

When sediment has filled to the level of the spillway, another plug can be constructed above the old plug, if further aggradation is desired. This process can be repeated until the gully has been healed. Heede (1976) provides criteria for proper spacing of gully plugs and design of spillway aprons.

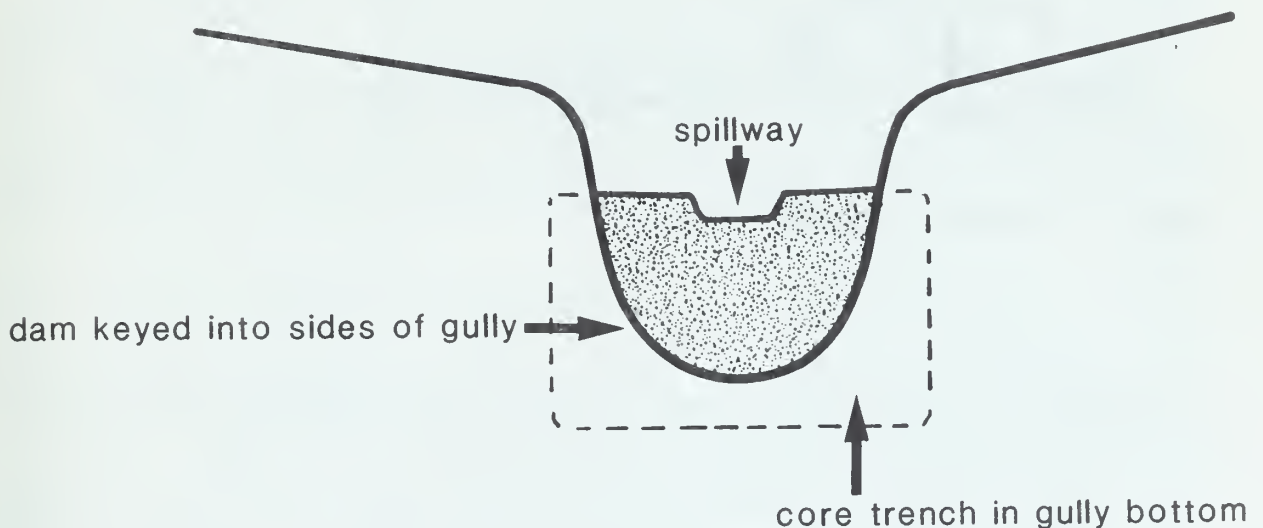


Figure 17. Proper construction of a gully plug.

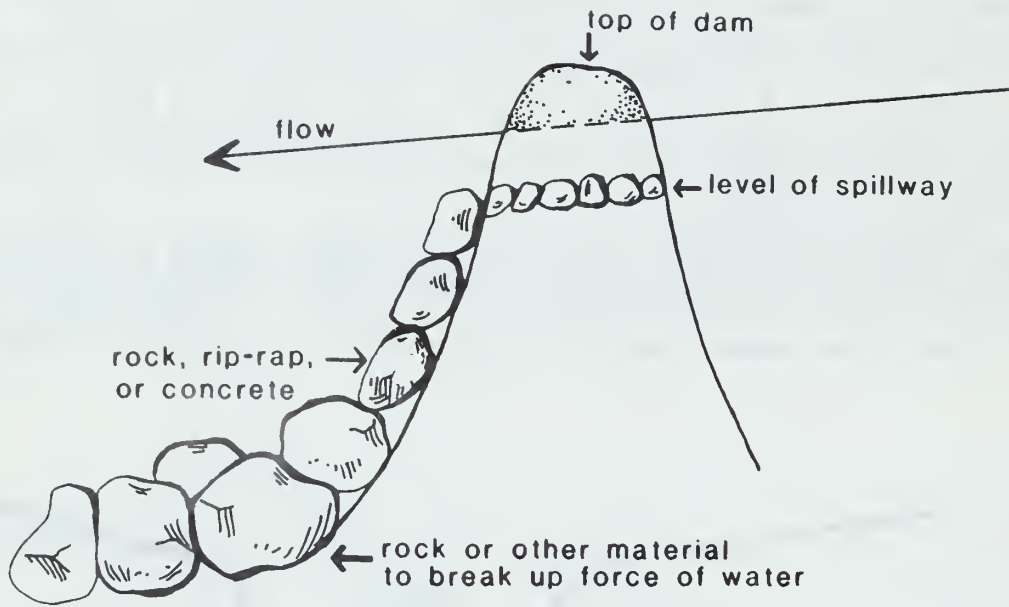


Figure 18. Spillway construction.

A gully headcut can be controlled by structures similar to those used for gully control. Heede (1976) points out that headcut control structures should be porous, though properly filtered, and located slightly downstream from the headcut. The headcut itself, should be excavated.

In the case where gully systems are symptoms of upstream watershed conditions, gully plug controls may provide fewer benefits than a program of upstream watershed stabilization or rehabilitation.

Surface Erosion of Shale Badlands

Steep dissected shale badlands contribute higher amounts of sediment and TDS on a per area basis than low-relief shale lowlands. In general, carefully designed sediment plugs located at the base of steep shale badland formations (Fig. 19) can effectively trap sediments and salts. If basin areas are small (less than 20 acres), plugs can be easily constructed by bulldozers using available shale soils (e.g., Mancos shale) which are essentially impervious to water and can be bulldozed into plugs with no further treatment. In cases where permeable materials are used, some type of clay or chemical lining may be required.

Sediment plugs should be graded from the upstream end to avoid downstream impacts and to increase their retention volume. The side slopes should be no steeper than 1:1. Plug height should be designed in conjunction with basin area to catch all runoff from a design storm after allowing for decreasing basin capacity due to sedimentation. Typical design sedimentation ratios are discussed elsewhere in this report. Plugs should be located close to the base of badland formations to maximize the proportion of sediment and salt trapped per unit of runoff. If possible, plugs should be located to provide maximum surface area per unit height of accumulated water and sediment. As plugs fill with sediment, their useful life will end. This occurs when the available capacity is no longer adequate to totally contain a design storm discharge. At this point, either a new plug must be added on top of the trapped sediments (Fig. 20) or an erosion resistant spillway must be provided to keep the existing structure from being over-topped and damaged.

Surface Erosion from Saline Rangelands

Contour furrows, trenches, retention dikes, and retention dams are all watershed management techniques used to reduce runoff erosion and sediment yields from rangelands and to provide increased water for plant production and livestock. They will also provide salinity benefits proportional to the amount of salt in the controlled runoff and sediment. Contour furrows sufficient to provide good watershed condition. Contour trenches, dikes and retention dams will control sediment and salt runoff, but will require periodic maintenance to continue functioning effectively.

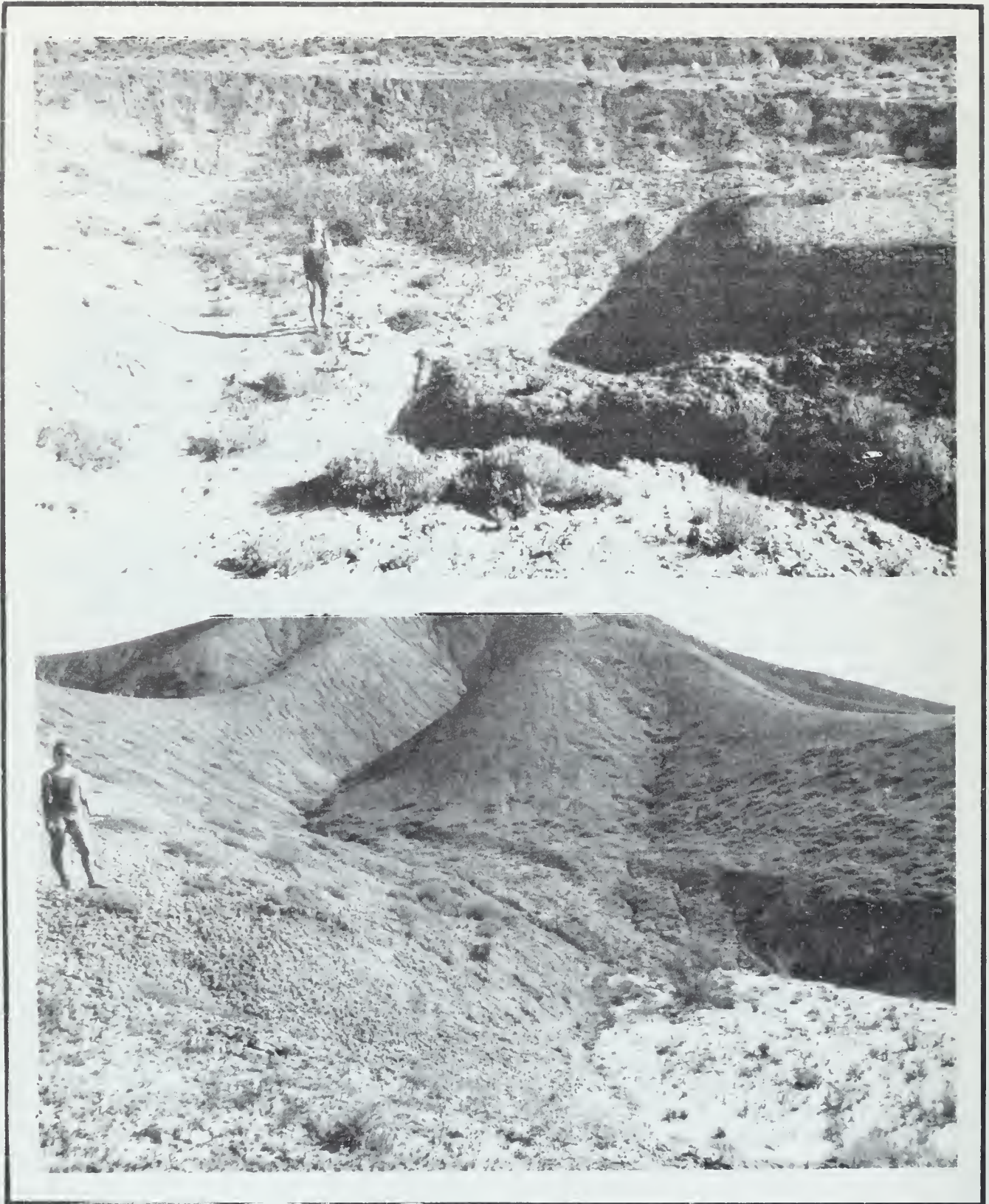


Figure 19. Sediment plugs located at base of a steep shale badland.

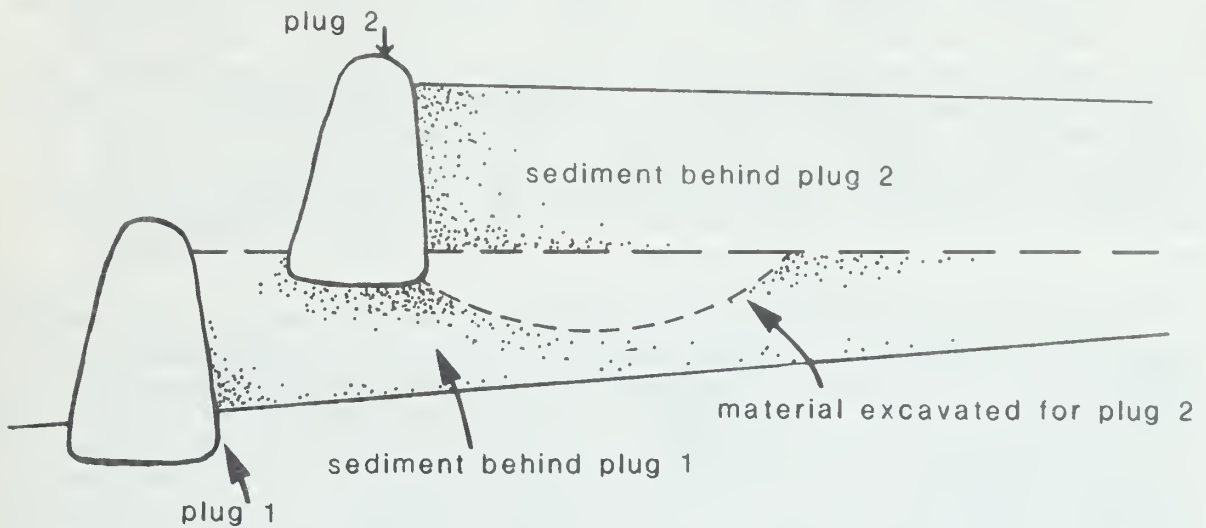


Figure 20. New sediment plug located on top of a previously-filled sediment basin.

Contour furrows are generally constructed with an Arcadia Model B (RM-15) contour furrow machine. Furrows constructed with this machine are spaced at 1.5 m (5-ft.) intervals, have a top width of 50 cm (20 in) and are roughly 20 cm (8 in) deep. Furrows are usually constructed within the context of a program of reseeding and grazing management. Furrows are not recommended on slopes greater than 10%, and are most effective in medium to fine textured soils. Furrows have finite lives (Branson et al., 1966), which are a function of their storage capacity in relation to runoff and erosion at the site. When functioning properly, they eliminate most runoff from a site. The benefits of furrowing and related management may be long lasting if cover improves and causes reductions in surface runoff and erosion.

Neff and Wight (1982) provide the following recommendations for effective contour furrowing, furrows should:

1. follow the contour.
2. have well constructed intra-furrow dams.
3. be constructed at design depth.
4. be properly spaced.
5. skip natural waterways.
6. be constructed in blocks.
7. be planned as an integral part of range resource management.
8. be constructed in the fall.

Contour trenches are similar to furrows but are larger--90 to 120 cm (36 to 48 in) deep--and more widely spaced (Fig. 21). The main purpose of trenching is to eliminate all surface runoff from a site. While trenches may not provide as much benefit to on-site plant production as furrows, they may be useful in highly saline sites where vegetation response to watershed treatments is generally poor anyway. Trenches can be designed to be long-lasting. In addition to the sources cited above, Noble (1965) provides guidance on the design of contour trenches, and criteria for determining the suitability of a site for trenching. In general, trenches should be sized and spaced to contain all run-off and to allow for some decrease in capacity due to sedimentation. Avoid live water courses and areas with a history of mass soil movement.

The BLM has widely used retention structures for erosion control and livestock water. Properly designed, they trap all incoming water, sediment and salt. Retention reservoirs must be impermeable to function for salinity control. Retained water is lost by evaporation. To function for salinity control, dams must be designed to trap all incoming runoff, and have sufficient storage capacity for sediment delivered for a finite design life. A spillway should be designed and constructed for all retention structures. The spillway needs to pass extreme hydrologic events (e.g., 100-yr discharge) without damage to the structure or the downstream channel. While a retention structure will cease to function for salinity control after it is filled with sediments in excess of its design capacity, a proper spillway will keep the structure from failing and becoming a future source of salt and sediment. Maintenance of retention structures--either by excavating stored sediments or by increasing their effective height--will allow the structures to function beyond their design life for salinity control.

Low dikes on gently sloping streamside areas can also be used to retain large volumes of runoff and provide increased soil moisture for plant growth. A small diversion dam generally has to be placed in the main channel, to allow runoff to be directed into the dike system. The cutoff can be designed to allow flows over a certain design level to bypass the dam and proceed downstream without entering the dike retention structure.

In the highest salinity areas retention structures are usually the only practical management alternative. The feasibility of constructing these types of structures is dependent, in part, upon identifying secondary benefits, including flood control, water supply, and wildlife habitat.

In moderate salinity areas, sediment and salinity benefits associated with runoff retention will be less than in the highest salinity areas. Projects in these areas need greater emphasis on secondary benefits, especially vegetation production and riparian enhancement. Depending upon site conditions, several alternatives are available:

1. On small (2-10 mi²) tributary washes with slightly to moderately incised gullies and flat, gently sloping (<3%) alluvial bottoms, small diversion dams and low water spreader dikes can be constructed to retain runoff and irrigate vegetation. This type of project is being implemented for salinity control at Elephant Skin Wash, Montrose District.

2. On flat, gently to moderately sloping uplands with high runoff potential, contour trenches or furrows can be used to reduce runoff and downstream (in-channel) erosion. Furrows may provide some benefits to vegetation production. Trenches generally don't.
3. Small washes with gentle slopes (<2% and slightly to moderately incised channels may be candidates for well constructed gully plugs. Gully plugs do not retain much salt or sediment but the sediment wedge which develops behind them, and extends upslope above the elevation of the spillway, functions to reduce gully bank erosion and down-cutting in unstable channels.

In developing a salinity control program through watershed management, it may be desirable to plan a mixture of treatment techniques which will optimize both costs and the effectiveness of salinity control. For example, sediment plugs in badland portions of a watershed may selectively remove large amounts of sediment, water and salt, thus allowing downstream retention dams to function longer and more cost effectively for runoff, erosion and salinity control, and provide higher quality water for livestock use. In another situation, a mix of gully plugs and retention dams may serve to stabilize a channel system activated by downstream base level changes and provide improved forage and wildlife habitat conditions by developing streamside riparian habitats and prolonging the period of active stream flow. Finally, in a third example, contour furrows, seeding and grazing management may be used to improve range and watershed condition and reduce salinity runoff. Retention dams may still be used to catch water from other sites and provide an on-site surface water supply.



Figure 21. Contour Trench on Mancos Shale.

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